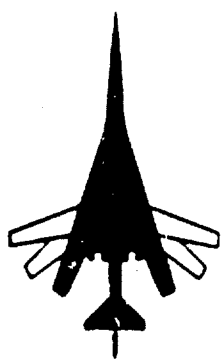
SUPERSONIC TRANSPORT PROGRAM
PHASE II-C

BI-MONTHLY TECHNICAL PROGRESS REPORT

CONTRACT FA-SS-66-5

NOVEMBER 1966



D6-18110-8

THE BOEING COMPANY

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CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

I SUMMARY OF PROGRESS

A. <u>Configuration Refinement</u>

The principal effort during the past two months has been directed toward validating the aerodynamic efficiency (L/D), that was the basis of the performance calculations presented in the September 6th Phase III proposal documentation, and improving the longitudinal control characteristics. Both of these objectives were achieved and the configuration improvements responsible are embodied in the Model B-2707-100 as described in document V1-B2707-5, which was submitted to the FAA on November 14, 1966.

Wind tunnel testing conducted during the past two months has proved an L/D = 8.2 for the Model B-2707-100. The aerodynamic improvements that were made included:

1. Revised wing camber and twist, providing lower drag-due-to-lift.
2. The incorporation of a twin-aisle passenger cabin arrangement; resulting in an improved body shape with lower wave drag and reduced sonic boom.
3. Improved elevon actuator arrangement, permitting elimination of actuator protrusions with resulting lower drag.
4. Positioning the G.E. engines rearward resulting in lower drag.

Longitudinal control has been improved by:

1. Increasing elevon area by 12 percent, which produces more control authority.
2. Changing the landing wing sweep position to 20°, reducing trim requirements and improving control capability.
3. Incorporation of a direct lift system utilizing spoilers, which effects improved flight path control for approach and landing.
4. Locating takeoff CG between 61 and 62 percent, which provides more than ample control for takeoff rotation with the changes noted above. The B-2707-100 incorporates a CG indicating device employing landing gear strain gages for accurate placement of the CG during airplane loading.

B. <u>Configuration Management</u>

The Model Specification and Subsystem Specifications are currently being updated to accommodate the B-2707-100 configuration and the FAA comments pertinent to the September 6th Phase III proposal doc[illegible]ion. Revised specifications are scheduled for FAA submi[illegible]he end of December.

I. SUMMARY OF PROGRESS (continued)

C. Wing Pivot Bearing Development

Extensive testing is continuing on the two-inch wing pivot bearing test program. One of the bearing materials tested appears to have outstanding wear characteristics based on preliminary test results. It is a teflon-dacron bearing utilizing a Reichold A5900 adhesive developed by the Rex Chain Belt Company. This bearing accumulated 1,846,000 cycles before failure, which is the highest number recorded to date for any bearing tested.

D. Flutter Test Program

Testing of a 1/20-scale flutter model in the Langley Research Center 16-foot Transonic Dynamics Tunnel was completed in October. Both 72° and 42° wing sweep positions were investigated. The model successfully withstood higher dynamic pressures than those represented by 1.2 V_D scaled boundaries with no evidence of flutter.

E. Failsafe Testing

The second failsafe test on the Ti-6Al-4V lower surface of the full-scale wing box test section has been completed. A broken stringer was simulated by incorporating a saw cut in the stringer. A design failsafe load was applied without incident. Subsequently, saw cuts were progressively added in the skin in the vicinity of the cut stringer. Upon application of design failsafe loads, a skin crack extended into fastener locations at adjacent stringers and was arrested. The test has demonstrated that the number of cycles required to extend cracks is more than ample to allow detection by inspection and that failsafe loads can be sustained on severely damaged sections without producing catastrophic effects.

F. Engine Inlet Development

A series of 1/10-scale inlet low speed performance tests were conducted in late November. The test model simulated the B-2707-100 configuration and the Phase III proposal inlet. Substantial inlet performance improvements over previously tested configurations were noted. The three major reasons for the improvements are:

1. Improved takeoff door design.
2. Aft movement of engine and inlet, providing improved wing flap-inlet relationship.
3. Improved flow channel through wing flap contact.

The tests indicate no distortion or turbulence which would cause engine performance losses during takeoff, landing, or go-around with flaps down.

III DESCRIPTION OF TECHNICAL PROGRESS

10 AIRFRAME – GENERAL

1001 System Integration

10011 CONFIGURATION DEVELOPMENT

The primary objectives of configuration development in work this period were improvement in cruise lift-drag ratio and in low speed longitudinal control of the B-2707. Moving the engines aft, changing the body contours, changing the wing shear, and eliminating the eleven actuator fairings reduced the cruise drag coefficient by about 0.0007, bringing the L/D up to 8.2. Marked increase in longitudinal control at low speed was achieved by providing a 20° wing sweep position, positioning of the CG at a near-optimum takeoff location, and the use of direct lift control by spoiler modulation in final approach. These developments were reported orally to the FAA on 28 October and 14 November; and incorporated in Document V1-B2707-5, "Model B-2707-100 Description," submitted 14 November.

The CG control work has continued. Practicability of ground CG indication by strain gage instrumentation of all five landing gear units or by the nose gear alone has been verified. Study work is proceeding on failure modes and reliability of an automatic CG control.

10014 PERFORMANCE ANALYSIS

Wind tunnel testing during the past 10 weeks has proved drag polars which completely verify the payload range performance submitted in the Aerodynamic Design Report Document V2-B2707-3 on September 6. Analyses of the FAA wind tunnel model test results have permitted performance calculations which essentially agree with the September data. All of the new performance data (including the effect of new General Electric engine data submitted to Boeing on October 7) was presented to the FAA on November 14 in Document V1-B2707-5 Model B-2707-100 Description.

1002 Design Analysis

10021 AERODYNAMIC ANALYSIS

(1) Takeoff and Landing Configuration

Detailed analyses have been made of three low speed wind tunnel tests of the FAA wind tunnel model (Boeing designation SA-981). These tests performed in the University of Washington wind tunnel during August, October, and November have provided the basis upon which performance, stability, and control data have been verified for the B-2707 and B-2707-100. Data obtained from these tests have been presented in Document V1-B2707-5 (Model B-2707-100 Description) and in Boeing Document D6A10433-1 (B-2707 Longitudinal Control Refinement Program). These documents show the results of the low speed wind tunnel tests in terms of takeoff and landing performance and low speed control effectiveness.

III Description of Technical Progress (continued)

(2) Cruise Configuration

Document D6A10432-1 (B-2707 Cruise (L/D) Verification Program) has been expanded to include analysis of recent supersonic wind tunnel results. Extrapolation of wind tunnel data to full scale, trimmed, airplane conditions has shown that the configuration modifications described in Document V1-B2707-5 have yielded drag improvements such that the lift/drag ratio levels assumed for performance calculations, through the supersonic Mach number ranges, have essentially been met or exceeded. In addition to the data extrapolation, the additions to Document D6A10432-1 include a complete description of wind tunnel model geometry and comparison with the airplane; and also a comparison of wind tunnel results with theoretical analyses.

10023 STABILITY AND CONTROL

Studies conducted since submittal of the B-2707 Phase III Proposal have resulted in large improvements in longitudinal control capabilities. The B-2707 has been modified to incorporate revised center-of-gravity management, reduced wing sweep for landing, Direct Lift Control, and a redesigned actuation system for the tip elevons. These modifications ensure satisfactory control for all flight conditions including operation following failure of two hydraulic systems. The modified airplane (designated the B-2707-100) and the improved longitudinal control capabilities are described in Document V1-B2707-5, "Model B-2707-100 Description", November 14, 1966 and in Document D6A10433-1, "B-2707 Longitudinal Control Improvement Program."

10024 AERODYNAMIC WIND TUNNEL TESTS

Aerodynamic testing during the October-November period and proposed through December is shown on the schedule chart, Fig. 1. Wind tunnel occupancy time for aerodynamics totaled 537 hours during October and November.

(1) Tests Completed

University of Washington Aeronautical Laboratories (UWAL) Test No. 872, SA-981 E-1, .0367 scale. Tested October 17 through 22. Purpose: To improve landing longitudinal pitch control at forward CG locations.

UWAL 875, SA-981 E-2, .0367 scale. Tested November 19 through 23. Purpose: Evaluate landing performance of B-2707-100 configuration.

Boeing Transonic Wind Tunnel Test No. 1005, SA-868 M-4, .055 scale. Tested November 14 through 21. Purpose: To continue boundary layer control development using full span, leading edge blowing.

	WIND TUNNEL MODEL NUMBER AND DESCRIPTION	OCT	NOV	DEC	
LOW SPEED	SA-981E-1 .0367 Scale Pitch Control Improvement Studies		UWAL 872		
	SA-981E-2 .0367 Scale B2707-100 Landing Config. Evaluation			UWAL 875	
	SA-868M-4 Full Span L.E. Blowing Studies			BTWT 1003	
TRANSONIC					
SUPERSONIC	SA-996I-4 .0152 Scale Cruise L/D Verification Program; B2707-100 Configuration Development		BSWT 371,373	BSWT 375,376	
	SA-983I-1 .015 Scale Stability & Control Improvement Program; B.L. Transition Studies		BSWT 374		
	SA-966I-4 .0152 Scale Directional Stability Improvement			BSWT 376B	
	SA-841I-23 .0162 Scale Wing-Tail Slot, Spoiler Study				
	SA-968I-1 .015 Scale Aeroelastic Effects Model				

Tests Completed | Tests Planned

Figure 1. Aerodynamic Wind Tunnel Test Schedule

10024 Aerodynamic Wind Tunnel Tests (continued)

Boeing Supersonic Wind Tunnel (BSWT) Test No. 371, SA-966 I-4, .01523 scale. Tested October 7 through 12. Purpose: Initial testing of L/D verification program.

BSWT Test No. 373, SA-966 I-4, .01523 scale. Tested October 24, 25, and 28 through 31. Purpose: To conclude L/D verification program and evaluate B-2707 speed growth potential to Mach = 3.8.

BSWT Test No. 374, SA-983 I-1, .015 scale. Tested October 26 through 28 and 31. Purpose: Stability and control improvement program and initial boundary layer transition studies.

BSWT Test No. 375, SA-966 I-4, .01523 scale. Tested November 8 through 11 and 30. Purpose: To develop high speed B-2707-100 configuration.

BSWT Test No. 375B, SA-966 I-4, .01523 scale. Tested November 22 and 23. Purpose: To evaluate directional stability improvement potential of forebody strakes.

(2) Future Test Planning

Future plans include testing a model which incorporates the wing-tail slot into a spoiler design for improved lateral control. A new model (SA-968) to study high speed aeroelastic effects is also planned. Further B-2707-100 configuration development tests will be conducted as required.

1003 Maintainability

The principal Maintainability effort during this period has been in support of design improvement engineering for the B-2707-100 configuration.

10030 GENERAL

Maintainability test requirements for the Flight Control System Simulator were prepared for inclusion in the Flight Control System Simulator test program. These test requirements include an evaluation of AIDS parameters and sensors, and an evaluation of maintenance requirements of FCSS Hardware.

10030 GENERAL (continued)

Maintainability personnel participated in four conferences during this reporting period.

- Review of B-2707 Maintainability and Reliability Program with American Airlines technical staff at Tulsa.
- Review of United Airlines current maintenance program with United Airlines personnel at San Francisco.
- Attended the Federal Aviation Agency Structural Reliability Symposium in Washington D.C.
- Attended the Air Transport Association Engineering and Maintenance Conference in Los Angeles.

10031 MAINTAINABILITY ANALYSIS

Revision A of Document D6A10265-1, "Maintainability Analysis," was released to incorporate new data with respect to the airframe subsystem. The change was negligible and had no significant effect in the originally reported results.

Maintainability analysis summary data was updated and charts were prepared for inclusion in D6A10469-1, "SST Program Progress Report - Reliability and Maintainability," copies of which were left in Washington on October 28, 1966.

Two procurement specifications, the Air Induction Control Pressure Transducer Specification 60A10036 and a Preliminary MLG wheel and Brake Specification 60A10026, were reviewed for maintainability requirements. Maintainability analysis data including Task Identification, Task Time, Task Frequency, Identification of Support Resources, Manhours, and Material Costs for Repair and Overhaul have been requested of the suppliers.

Maintainability inputs have been made for several trade studies.

10032 MAINTENANCE ANALYSIS

The maintenance analysis is being reviewed for possible changes due to the B-2707-100 configuration. More detailed procedures for accomplishing and integrating the Phase II maintenance analysis are being developed.

10033 MAINTAINABILITY STUDIES

Document D6A10342-1, "Evaluation of the AIDS for the SST," was released. Copies of this document have been distributed to the FAA and interested airlines.

III Description of Technical Progress (continued)

1004 Reliability

10040 RELIABILITY-GENERAL

The existing manual on the Automatic Reliability Mathematical Model (ARMM) is being revised to bring it up to date, and to make it more useful.

The Fleet Integrated Reliability Math Model (FIRMM) is being documented.

Existing Boeing programs are being examined to determine if there are portions of them that could be adapted as supporting subroutines for ARMM, and FIRMM.

10041 RELIABILITY DESIGN SUPPORT

Reliability Analysis Documents, D6A10064-1 to D6A10064-17 have been reviewed for consistency. Allocations have been revised below the sub-system level in relation to the complexity of the proposed hardware. Reliability Analysis Documents will be reissued (or replacement pages provided) to reflect these minor revisions. The following revised documents have been released:

D6A10064-4(B)	Reliability Analysis Document - Automatic Flight Controls
D6A10064-5(B)	Reliability Analysis Document - Communications
D6A10064-6(A)	Reliability Analysis Document - Electrical and Lighting
D6A10064-10(A)	Reliability Analysis Document - Hydraulic Power
D6A10064-11(A)	Reliability Analysis Document - Landing Gear
D6A10064-12(B)	Reliability Analysis Document - Navigation and Flight Instruments
D6A10064-15(A)	Reliability Analysis Document - Air Induction

The following document has also been released:

D6A10064-18	Reliability Test and Evaluation Planning Data

Development of the FCSS Test Plan, D6A10441-1, was supported with an integrated input from the Design Support organization for Reliability, Maintainability, Safety, and Human Engineering considerations.

10042 RELIABILITY ANALYSIS

Subsystem dispatch reliability allocations, previously specified only in maximum allowable delay frequencies, have been further allocated in terms of allowable dispatch critical item failure rates and mean unscheduled task times for level 3 of the Work Breakdown Structure. This was done to provide more definitive design guidance, as well as to allow more effective design assessment.

III Description of Technical Progress (continued)

10042 RELIABILITY ANALYSIS (continued)

Preliminary copies of Document D6A10409-1, Supersonic Transport Program Progress Report - Reliability and Maintainability, were provided to some FAA management personnel during an oral discussion in October. The document will be released and distributed through normal channels during the next reporting period. Among the significant data summarized therein is a trade study relating high lift capability with tires and brakes in dispatch reliability terms. The study shows that special features of the Boeing design associated with the variable sweep wing, high lift capability, and flaps can be expected to result in approximately 0.3 delays per 1000 departures due to these items. However, due to the low landing speeds and consequent gains due to reduced tire and brake wear provided by these devices, the study shows these features produce a net return in terms of reduced delay at a 12 knot or greater landing speed reduction compared to the landing speed possible without these features, with other considerations remaining constant.

1006 Configuration Management

The September 6 issue of Model Specification D6-17850, and the subsystem specifications are being updated for resubmittal to the FAA on December 31, 1966. The specification revisions include the incorporation of airplane guarantees, the B-2707-100 configuration details, and the Boeing action in response to questions and comments submitted by the FAA on November 28, 1966.

1007 Product and System Safety

10070 SAFETY GENERAL

The development of operating procedures and other command media has been continuing. A Division Directive has been completed and submitted for management approval. This directive implements Corporate Policy 4E1 concerning product and system safety engineering, and establishes an SST Division Safety Program as a management discipline directed toward product excellence.

The SST system safety program has been strengthened through participation in meetings and seminars with Company, national, and international safety organizations. A paper titled, "SST System Safety Program" by A. T. Curren and C. B. Stewart, The Boeing Company, was presented by Mr. Curren to the CASI/AIAA/CGASC Aviation Safety Meeting at Toronto, Canada, October 31, 1966.

10070 Safety General (continued)

A member of the SST System Safety organization attended the Flight Safety Foundation 19th Annual International Air Safety Seminar, 15-18 November at Madrid, Spain.

A Boeing inter-divisional System Safety Engineering Seminar was held October 19 at Seattle to exchange ideas and establish methods for collection and dissemination of safety data.

10071 DESIGN SUPPORT

A system is being developed for analysis of accident and incident data. Cause factors may be correlated to specific airplane design characteristics on a statistical basis. Thus, design criteria based on operational experience can be made available to designers.

Engineering studies are being made of results of the FAA/Air Force program monitoring cosmic radiation using the modified RB-57F airplane. Twenty-five flights were flown during October and November using instruments fabricated by Solid State Radiations Inc. (SSR). The president and the project engineer of the SSR visited Boeing on November 15 and explained their instrument and the recording methods. Contact with Air Force personnel has indicated that cosmic activity has been recorded by the RB-57F experiments. Daily reports are received on Sun spot, flare, and proton activity from a world-wide network. A system is being developed to analyze the coded messages and to determine their applicability to airline dispatch use. The accuracy of warning from this network will be judged by data from the RB-57F flights.

10072 REQUIREMENTS ANALYSIS

The configuration alterations of the B-2707-100 described in V1-B2707-5 have required an updating of the compressor and turbine disc failure study. This effort is underway, and will include a fault tree of possible structure penetration ensuing from disc failure.

Results of this fault-tree analysis will be used as a basis for establishing optimum configuration (and redundancy) for critical components currently in the potential spray path for disc failures.

Fuel Containment

Physical properties of an improved fluorosilicone fuel sealant have been measured after heat and fuel exposure. Results obtained on 94-002 under the same conditions are listed for comparative purposes. Results are given in Table A. The performance of Dow Corning 94-512 substantiates earlier predictions for significant advances in fluorosilicone sealant technology. After 15 cycles of fuel and heat (500°F) exposure as indicated, the properties of 94-512 were essentially unchanged.

Table A Sealant Properties

Sealant Material	Physical Property	Cycles*				
		0	2	6	10	15
Dow Corning 94-002	Durometer, Shore "A"	50	46	45	Specimens Crumbled	
	Tensile Strength, psi	600	565	450		
	Ultimate Elongation, %	250	190	230		
Dow Corning 94-512	Durometer, Shore "A"	30	23	31	29	32
	Tensile Strength, psi	290	220	225	220	240
	Ultimate Elongation, %	300	280	280	300	250

* One cycle consists of: 48 hours at 250°F in JP-5, followed by 96 hours at 500°F in fuel vapor and nitrogen.

Electrically Conductive Coatings on Glass

The vapor deposited gold coatings which are proposed for use on The Boeing 2707 are generally considered to be quite fragile. The susceptibility to damage by routine maintenance was investigated by subjecting 5 specimens of gold coated glass to 40 wash cycles each using a typical airline and Boeing technique. The bus-to-bus resistance of the coatings was measured between tests and was found to remain constant. The gold coated surface is expected to be subjected to only 10 to 15 washings during the service life of the airplane.

Although the resistance was unchanged, a few small, bright colored spots appeared in the coatings between the tenth and fifteenth washings. The yellow color of these spots implies that the silica overlay had been removed from these spots, exposing the gold beneath. With continued vigorous cleaning, however, the spots did not enlarge, nor did their number increase; therefore, the gold coatings are practical for use.

III Description of Technical Progress (continued)

1008 Materials and Processes (continued)

Exterior Finish

Four candidate exterior paints which passed previously reported screening tests are now being tested under simulated SST flight conditions. The test chamber is cycled between room conditions and flight conditions. Simulated flight conditions are 430°F temperature, 30 torr pressure, and ultraviolet radiation of an intensity and spectral distribution equivalent to one sun at 70,000 feet altitude. Temperature and pressure are maintained for two hours each cycle. Ultraviolet exposure is for one hour each cycle. To date 200 cycles have been completed. Specimens were examined after 13 cycles, after 103 cycles, and after 200 cycles. All specimens were originally white and showed slight yellowing after 13 cycles, which increased slightly at 103 cycles. No further increase in yellowing was noted after 200 cycles. The DeSoto paint showed fine cracking after 13 cycles. The cracking became progressively more severe as testing continued. The Midland paint, uncracked after 13 cycles, showed severe crazing and flaking after 103 cycles. Short, very fine cracks were found on the Rinshed-Mason paint after 200 cycles. To date, no cracking has been found on the Markal paint.

Emittance of Titanium

During a study of the infrared reflectance spectra of titanium surfaces, the emittance of Ti-6Al-4V was calculated as a function of temperature over the range from 70°F to 1700°F. The results are of interest for the SST and provide a basis for thermal calculations.

Both the total hemispherical emittances and the total normal emittances were calculated from theoretical equations and the known electrical resistivity of the alloy. The calculated emittances are compared to available experimental values in Table B.

The one experimental value for the total hemispherical emittance checks closely with the calculated value. This value was determined on a freshly etched surface. The Lion Optical Surface Comparator was used. The experimental values of the total normal emittances show greater deviation from the calculated values. However, below 800°F, the experimental and calculated curves are parallel. A total radiometric method was used for these determinations, which were performed on a polished surface. Such surfaces frequently show a higher emittance than freshly prepared surfaces due to a thicker oxide film on the polished surface. Above 800°F, the experimental values deviate further from the calculated values due to an increased oxidation rate in air.

Table B Emittance of Ti-6Al-4V

Temp. (°F)	Total Hemispherical		Total Normal	
	Theory	Etched (Exp.)*	Theory	Polished (Exp.)*
70	0.15	0.15	0.12	0.16
200	0.16	----	0.14	0.17
400	0.18	----	0.16	0.20
600	0.20	----	0.18	0.22
800	0.22	----	0.19	0.24
1000	0.23	----	0.21	0.31
1200	0.24	----	0.22	0.55
1400	0.25	----	0.23	----
1600	0.26	----	0.24	----
1700	0.26	----	0.24	----

* "Thermal Radiative Properties of Selected Materials," DMIC, Report 177, Vol. 1, Nov. 15, 1962.

Extreme Temperature Grease Evaluation

Three candidate greases for extreme temperature use have been evaluated in rolling element bearings at 450°F. These greases are Krytox 240AC (formerly designated PR240AC by the DuPont Company), Chevron Research 66R-6715, and Marlin Rockwell EG551. They were selected on the basis of preliminary screening tests of candidates greases using a four ball friction and wear tester. Results of the screening tests have been presented in earlier progress reports. The bearing tests show that the Krytox 240AC grease provides lubrication of the 440C stainless steel test bearings for the longest time under oscillatory motions. Test results using an AN200K5ST full complement shielded ball bearing tested under a 1405 pound radial load (42% of rated capacity corrected for 440C stainless steel at 450°F) are shown in Table C. When an AW5AK bearing lubricated with Krytox 240AC grease was tested at 450°F under a radial load of 17% of rated capacity (approximately one-third the load used in the tests discussed above), 1,200,000 cycles (1000 hours) were obtained. Torque did not exceed 1.0 in-lb and the bearing appeared to be in ex-

cellent condition after the 1000 hour test. This shows that much longer bearing life can be obtained with the Krytox 240AC grease if the loads are reduced.

Table C Grease Performance Life in 440C Stainless Steel AN200K5ST Shielded Bearings at 450°F

Radial Load - 1405 lb (42% of rated capacity, corrected for 440 stainless steel at 450°F)

Thrust Load - 0

Motion - Oscillatory at ± 20 degrees and 20 cpm

Grease	Life		Remarks
	Cycles	Hours	
Krytox 240AC*, DuPont Co.	509,520	386	Bearing outer race broken, grease appeared to retain lubricity
66R-6715, Chevron Research Co.	326,000	247	Test stopped due to high torque, bearing badly worn
EG 551, Marlin Rockwell Co.	100,700	75	Grease carbonized

* Formerly designated PR 240AC

Low temperature torque tests have been conducted on the Krytox 240AC and Chevron Research 66R-6715 greases using the ASTM D-1478 test method. In these tests, starting and running torques were determined at -30, -40, and -50°F using 204 size ball bearings (20 mm bore) in which the race cavity is completely filled with the test grease. The lubricated bearings are soaked at these temperatures for one to two hours to ensure that they are at test temperature. Starting torque is taken as the maximum torque at the start of rotation and running torque is the average value after ten minutes. Values found in these tests are shown in Table D and indicate that low temperature torques of bearings lubricated with Krytox 240AC and Chevron Research 66R-6715 greases are high.

Table D Low Temperature Torque of Grease Lubricated Bearings – ASTM D-1478

	Temperature, °F	MIL-G-27549 Grease*	DuPont Krytox 240AC	Chevron Research 66R-6715
Starting Torque, g.-cm	-30	---	3,717	1,652
	-40	---	11,151	8,585
	-50	---	above 16,520**	above 16,520
	-65	N5000	---	---
Running Torque, g.-cm	-30	---	2,124	1,652
	-40	---	7,375	7,139
	-50	---	above 16,520	above 16,520
	-65	N500	---	---

* Added for reference only

** Scale limit is 16,520 g.-cm

These values emphasize the need for a dual lubricant system in which a dry film or lubricant compact does the job at subzero temperatures and the greases take over as the temperature increases. This type of system is being investigated.

Evaporation tests were conducted at 450°F to obtain an indication of the thermal stability of the greases under study. These tests were conducted by spreading approximately 15 grams of grease uniformly across the bottom of a 50 ml beaker. The beaker containing the grease was weighted to the nearest 0.001 g. and placed into a forced convection oven maintained at 450 ± 5°F. The grease samples were reweighted at the end of 1, 3, 7, and 14 days and weight losses of the grease determined. The evaporation data obtained for the Krytox 240AC, Chevron Research 66R-6715, and four other candidate greases are shown in Fig. 2. These data show that the Krytox 240AC and Chevron Research 66R-6715 grease (both of which contain perfluorinated oil base stocks) have the least weight loss due to evaporation or thermal decomposition at 450°F.

Wing Pivot Two-Inch Bearing Program

The test results shown in Table E on 2-inch-bore teflon woven journal bearings were obtained since the September report. Of particular interest is test No. 303, a vendor fabricated bearing. This bearing uses a proprietary curing cycle developed by Rex Chain Belt Co. The excellent long life of specimen No. 303 indicates a potential capability for this type of Bearing-adhesive System. It is noted that the adhesive without this cure can exhibit an extremely wide scatter range; however, further development work is planned to establish long life, reproducibility, and system reliability.

Vibration and Oscillation Bearing Tests

Four tests have been run to determine the resistance of teflon-fiberglass fabric bearings to simultaneous reversed loading and shaft oscillation conditions. Two of these tests have been completed. Results and test conditions are shown in Table F.

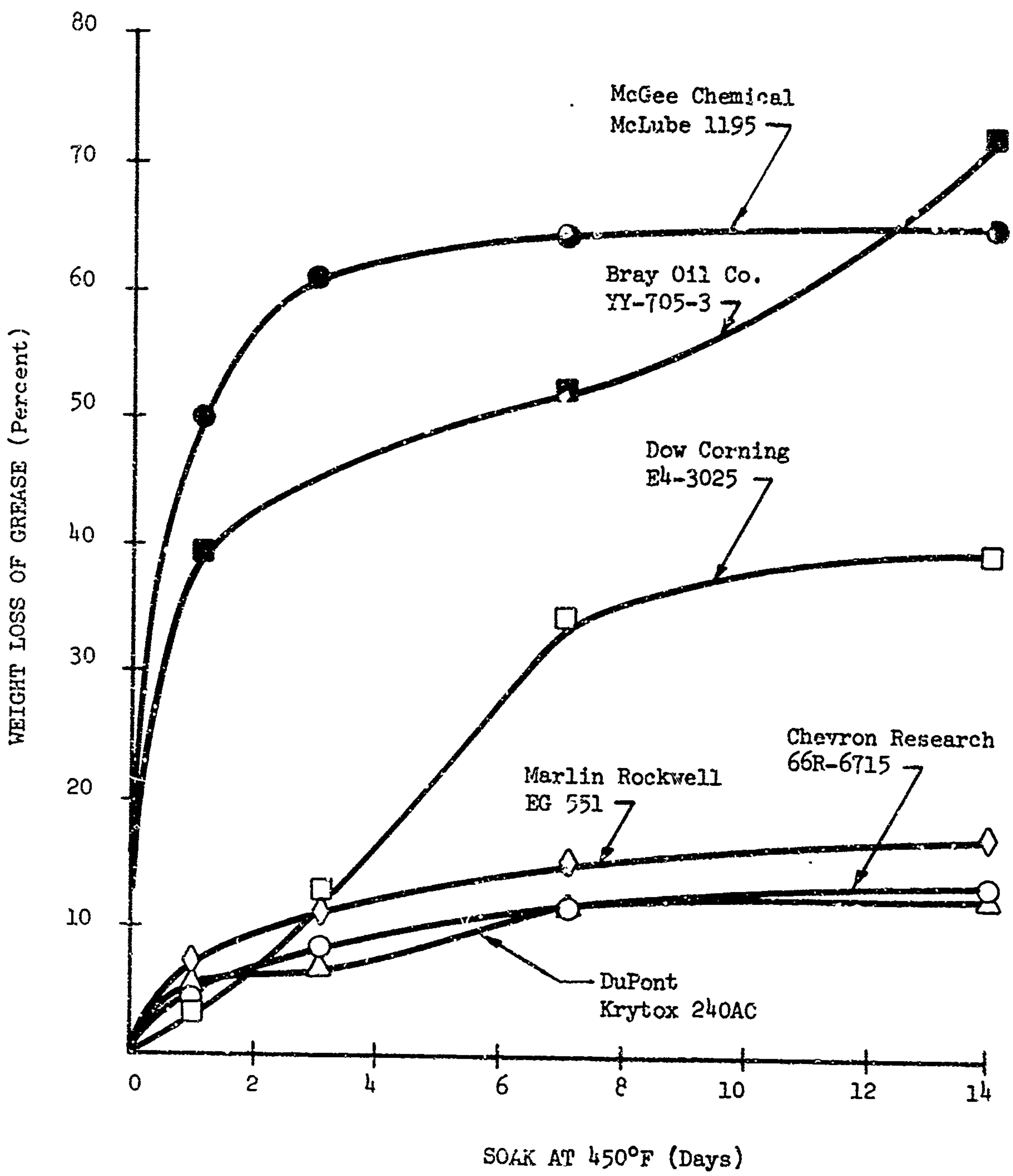


Figure 2. Relative Weight Losses of Candidate Supersonic Transport Greases at 450° F

Table E Materials Test – Two-inch Wing Pivot Bearing Program

Specimen Number	Test Conditions Load (ksi)	Test Conditions Temp. (°F)	Exposure Conditions Prior to Test	Adhesive Used	Fabric and Layup Angle Used	Bond-line thickness (mils)	Wear life [5] Cycle	Wear life [5] Test
309 [2]	20	300	1000 hrs @ 300°F	Reichold A5900	Teflon-Dacron @ 15°	7.6	401,175	77,146
294 [3]	20	300	1000 hrs @ 300°F	Reichold A5900	Teflon-Glass @ 45°	10.0	6,503	1,286
338 [1]	20	300	None	Epon 957	Teflon-Glass @ 45°	13.9	23,547	4,634
349	20	300	"	Epon 957	Teflon-Glass @ 0° [4]	14.2	80,119	15,864
342	20	300	"	FXM-34B-34. Polyimide	Teflon-Glass @ 45°	10.6	210,000	39,923
303 [2] [6]	20	300	"	Reichold A5900	Teflon-Dacron @ 15°	12.1	1,845,000	360,332
306 [2]	20	300	"	Reichold A5900	Teflon-Dacron @ 15°	13.5	605,567	118,207
305 [2]	20	300	"	Reichold A5900	Teflon-Dacron @ 15°	13.7	11,240	2,194
340 [1]	20	300	"	Unknown	Teflon-Glass @ 0°	9.1	4,188	824
341 [1]	20	300	"	Unknown	Teflon-Glass @ 0°	9.1	3,135	617
345	15	400	"	Epon 957	Teflon-Glass @ 45°	14.6	521,634	98,641
346	15	400	"	Epon 957	Teflon-Glass @ 45°	14.3	355,476	60,608
347	15	400	"	Epon 957	Teflon-Glass @ 45°	15.3	238,321	46,115
348	15	400	"	Epon 957	Teflon-Glass @ 45°	16.0	212,274	37,084
344	15	400	"	Epon 957	Teflon-Glass @ 45°	15.9	201,685	38,300

[1] Manufactured by Industrial Tectonics, Inc. Compton, Calif.
[2] Manufactured by Rex Chainbelt Co., Bearing Div., Downers Grove, Illinois
[3] Manufactured by Transport Dynamics, Inc., Santa Ana, Calif.
[4] Split Steel Tool was used
[5] Failure occurs when shaft wears through fabric-adhesive liner to metal ring
[6] **Proprietary cure cycle**

Table F Bearing Tests

	Load (psi)	Bearing Temp. (°F)	Reverse Load Freq. (sinu-soidal) (CPS)	Shaft Oscill. Freq. (CPM)	Shaft Oscill. Angle	Total Reverse Load Cycles	Total Shaft Oscill. Cycles	Total Radial Play (Inch)	
1	7000 ± 5000	450	20	20	[illegible]	12,937,000	233,334	.0140	
2	0 ± 5000	450	10	20		41,480	97,852	.0079	
2	0 ± 5000	450	10	20	±50°	27,600	1,125	.0046	3
2	0 ± 5000	300	10	20	±30°	753,640	24,094	.0037	3

1. Load applied to one side of bearing only.

2. Load applied to opposite sides of bearing.

3. Test stopped because bearing was loose in housing. Bearing has not failed.

1008 Materials and Processes (continued)

Titanium Net-Section Extrusions

A joint effort is being conducted with the H. M. Harper Company to improve the surface finish of titanium extrusions. In this program, Boeing will supply a glass that will serve as a protective coating during heating of the billet and as a lubricant while extruding. The H. M. Harper Company will furnish the billets and extrusion equipment.

Effect of Machining on the Fatigue Life of Ti-6Al-4V

A preliminary evaluation of the effects of various machine surface finishes and edge preparation methods on the fatigue life of Ti-6Al-4V, solution treated and aged at 1250°F, has been completed. S-N curves for chemical milled (RHR-14), ground (RHR-30), peripheral milled (RHR-250), peripheral milled (RHR-25), face milled (RHR-25), face milled (RHR-10), end milled (RHR-250), end milled (RHR-125), and end milled (RHR-50), were determined using reverse bending flexure, unnotched fatigue specimens.

Preliminary observations show that (1) grinding greatly reduces fatigue life, (2) machined surfaces with a 63 RHR or better surface finish are essentially equivalent in fatigue life, (3) peripheral milled surfaces up to 250 RHR surface finish are equivalent in fatigue life to 63 RHR or better surfaces prepared by the other methods tested, and (4) there is an abrupt decrease in the fatigue life of end milled surfaces rougher than 63 RHR.

Edge finishes were evaluated in tension-tension fatigue using a 0.090-inch thick unnotched specimen. S-N curves at R = 0.06 were determined for peripheral milled, peripheral-milled and sanded longitudinally, peripheral milled and sanded transverse, blanked and hand deburred, blanked and vibratory deburred, and machine nibbled and hand deburred specimens. The data indicates that (1) blanking seriously reduces the fatigue life, and (2) sanding transverse to the specimen axis causes some reduction in the fatigue life of the peripheral milled surface finish although probably not sufficient to be of concern on built up structure.

Mechanical Joint Studies

Ti-6Al-4V Rivet He ability

An evaluat_on of the effect of heat treatment on the headability of titanium alloy rivets was made using flat heading dies. The results

show that the headability is materially affected by heat treatment. For example, Table G indicates that there is a 1.60 ratio in the required load to crack the material heat treated at 1350°F for 4 hours and furnace cooled to 1050°F and that heat treated at 1500°F for 4 hours and air cooled. This method of testing is preferred over the formed die heading operation because of lower heading force requirements and better uniformity of data. Similar tests conducted with the formed die show an increase of approximately 40 percent over the flat die cracking force.

Table G Effect of Heat Treating on Flat Die Heading, 1/4" Diameter Ti-6Al-4V Rivets

Heat Treatment	Load to Crack (lb)
1350°F - 4 hours, furnace cool 1050°F, air cool	31,000
1500°F - 4 hours, air cool	20,000
1500°F - 4 hours, water quench	19,500
1650°F - 1 hour, furnace cool 1050°F, air cool	30,500

A286 Rivets

Additional exposure tests of lap shear specimens containing manual and precision drilled holes have been completed. The precision holes were drilled and reamed with a jig borer to 0.2550 ± 0.0005 inch and burrs were removed by hand honing and polishing. The manual holes were drilled with an air motor to 0.252- to 0.256-inch tolerance and no reaming or deburring was permitted. Holes purposely were out of round and the surface was scratched and rifled.

Figure 3 shows the effect of heading load, hole preparation, and exposure on joint fatigue life. Figure 4 shows the fatigue life of unexposed specimens headed with the same loads. After exposure, the fatigue life is generally reduced, and the fatigue life difference between specimens containing rivets headed at 24,000- and 32,000-pound load is also reduced. Finally, the rivets installed in manually drilled holes exhibited a fatigue life as good as those installed in precision holes. This indicates that hole preparation may not be critical.

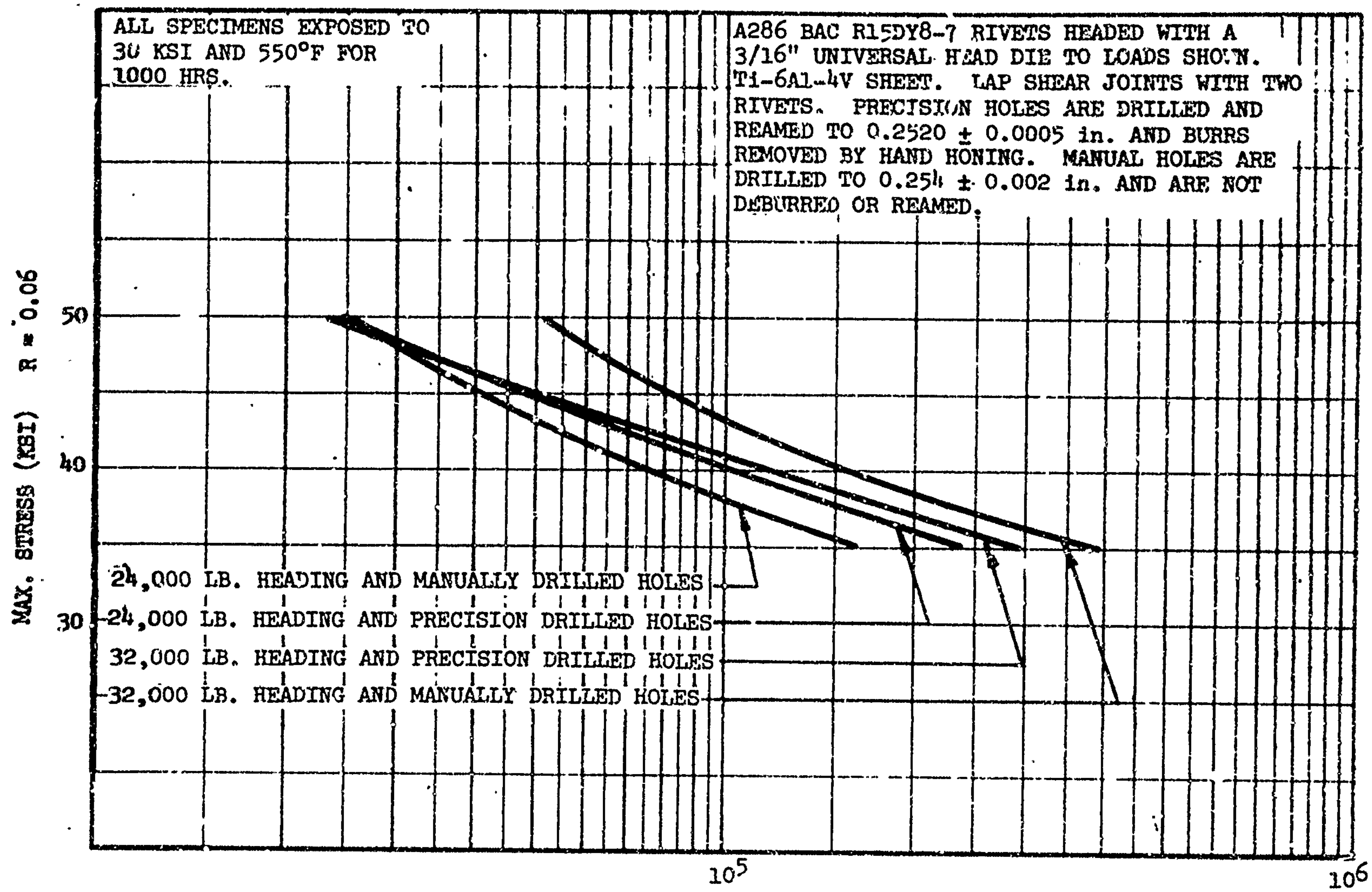


Figure 3. Comparison of Manual and Precision Drilled Holes ¼" Dia A286 Rivets

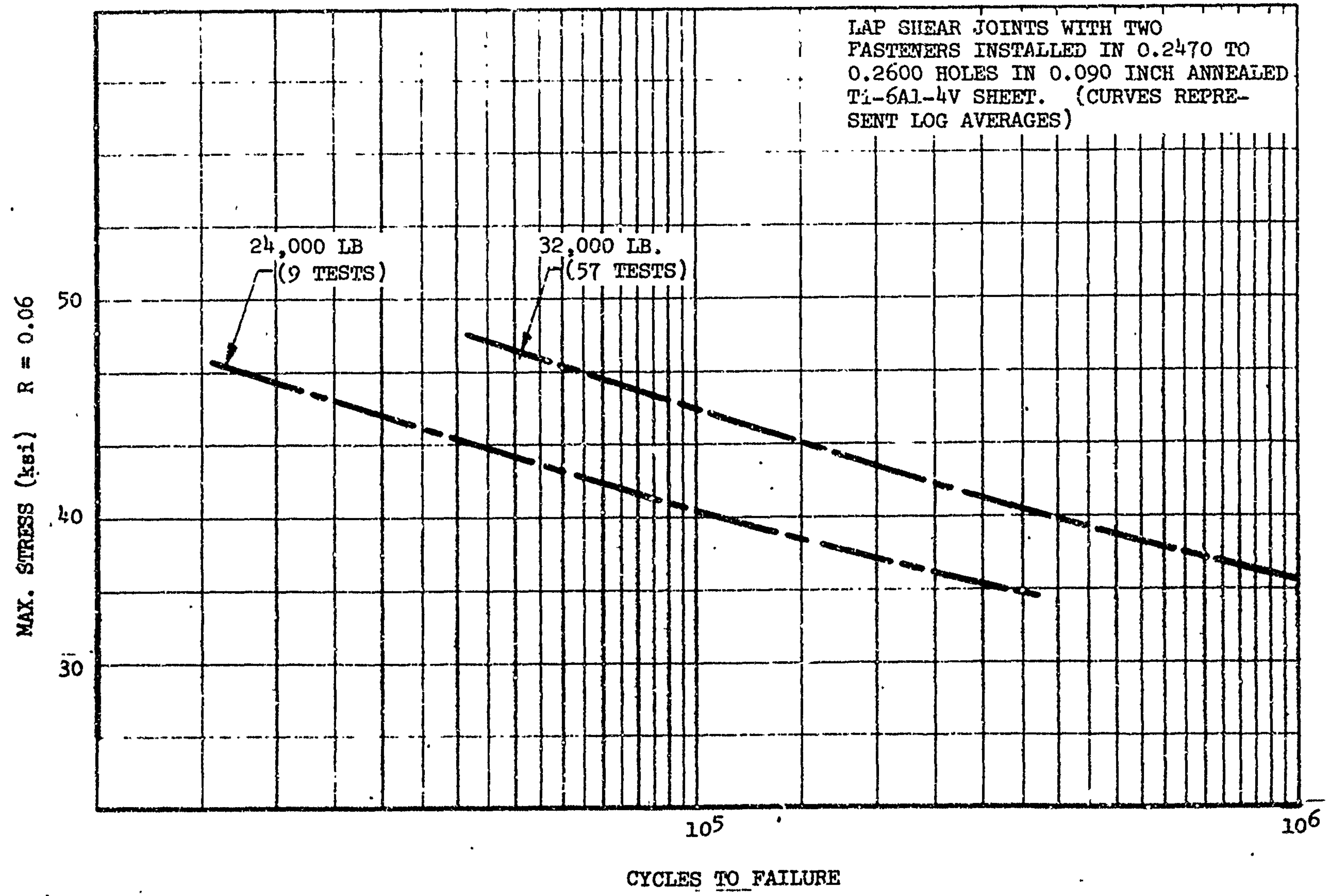


Figure 4. Heading Force Study – A286 Rivets, Universal Head Die, Manual and Precision Holes

III Description of Technical Progress (continued)

1008 Materials and Processes (continued)

Fluid-Tight Rivet Evaluation

Room and elevated temperature sealing characteristics of squeezed and gun driven A-286 and squeezed Ti-6Al-4V rivets were evaluated with regard to hole size, installation technique, and countersink head configurations. The evaluation was conducted by fatigue testing a four rivet lap joint specimen (see Figure 5) of 0.090 inch Ti-8Al-1Mo-1V with the edges sealed and fuel, or simulated fuel, under 14.5 psi pressure imposed at the joint interface. The fatigue loading involved a constant alternating load but with an increase in the mean load with each cycle until either the rivet strength is reached or the test machine limitation is attained. The loading schedules are shown in Figs. 6 and 7. Results of the tests are shown in Table H. By comparison with aluminum alloy rivet tests the A-286 rivets will be self sealing and the Ti-6Al-4V rivets may be self sealing.

All leaks occurred at the countersink heads of the rivets. Slug rivets driven into 82° - 30° countersinks sealed best. A-286 rivets sealed well at both room temperature and at 450°F, whereas Ti-6Al-4V rivets did not seal as well at 450°F as at room temperature. Squeezed rivets sealed more consistently than did the gun driven rivets.

In-Place Tube Welding

Seventy specimens have been in-place fusion welded and will be mechanically tested. The joint designs and materials are listed in Table I and Fig. 8. Both visual and radiographic examination indicated satisfactory weld quality. Some randomly scattered internal porosity, approximately 0.005 - 0.010 inch in diameter was found in a few specimens. These specimens are of particular interest because previous tests have indicated this type and quantity of porosity to have no effect on cyclic pressure and fatigue life. The additional data from the current series of tests will provide further basis for establishing defect allowables.

Fusion Welding of Ti-4Al-3Mo-1V Plate

Result of tensile tests of fusion welds in 0.25 inch thick Ti-4Al-3Mo-1V plate are shown in Table J.

1009 Mockups

The Engineering releases for the outboard wing leading edge mockup were completed November 2, 1966. Construction of the mockup is in work with completion scheduled for December 19, 1966. The remainder of the mockups planned for Phase II-C are complete and mockup reviews have been conducted.

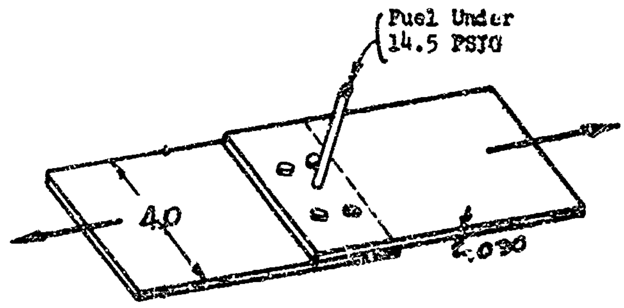


Figure 5. Specimen Configuration

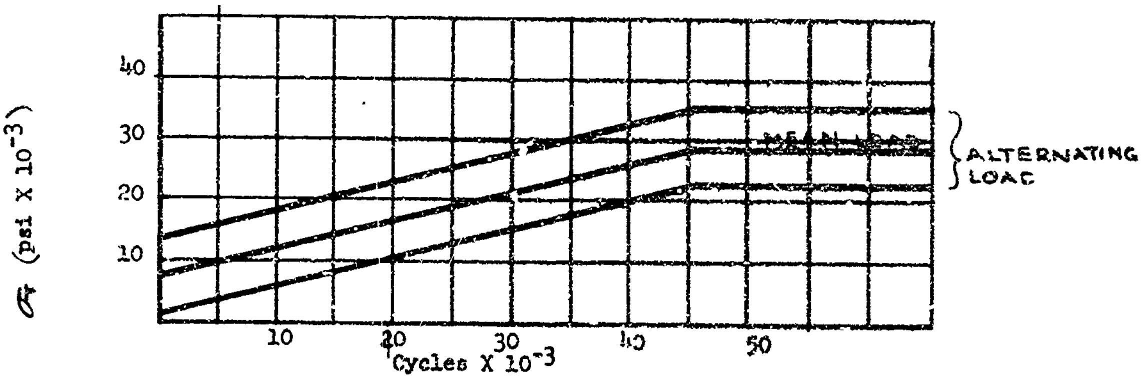


Figure 6. Test Schedule for 3/16" Dia Rivets

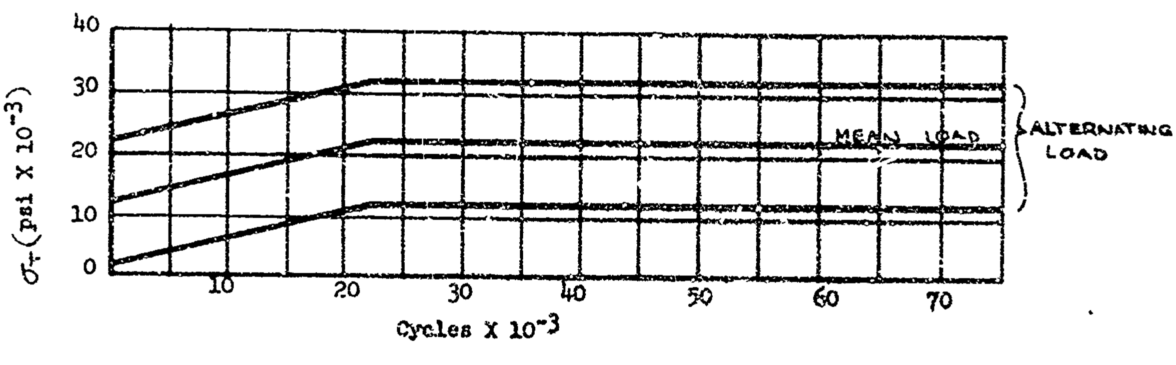


Figure 7. Test Schedule for ¼" Dia Rivets

Table H Rivet Test Results

Rivet DIA ±.0005	Hole DIA	Rivet Mat'l	Rivet Head Style	Rivet Installation	Test Temp	Cycles to First Leak
.1890	.190	A-286	Slug NASA CSK	Squeezed 13,000 lb	Room	17,000
	.194					39,000 [1]
	.198			13,000 lb		40,000
	.190			18,000 lb		40,000
	.194					40,000 [1]
	.198				Room	40,000
	.190				450°F	21,000
.1890	.194		Slug NASA CSK	Squeezed 18,000 lb	450°F	23,000
.2490	.250		100° CSK	Gun Driven 1.5 D	Room	20,000
	.254					27,000
	.258			Gun Driven 1.5 D		31,000
	.250			Squeezed 32,000 lb		40,000
	.254					40,000
	.258	A-286				43,000
	.250	6Al-4V				21,000
	.254	6Al-4V	100° CSK			23,000
		A-286	Slug NASA CSK		Room	71,000
		A-286	Slug NASA CSK		450°F	22,000
		A-286	100° CSK			22,000
.2490	.254	6Al-4V	100° CSK	Squeezed 32,000 lb	450°F	1,000

[1] Rivets Sheared - No Leaks Prior To Failure

Table I Joint Designs for In-Place Tube Welding

ALLOY	[4] JOINT TYPE	WALL THICKNESS (inch) SLEEVE	TUBE
321	Square Butt	----	.025
Ti-3Al2.5V	Square Butt	----	.015
Ti-3Al2.5V	Butt Insert [3]	----	.015
Ti 6Al2.5V	Butt Sleeve	.028 [1]	.028 [2]
Ti-6Al-4V	Sleeve Melt Through	.028 [1]	.028 [2]
Ti-3Al2.5V	Butt Sleeve	.015	.038
Ti-3Al2.5V	Sleeve Melt Through	.015	.038

[1] Sleeves Machined From Ti-6Al-4V Bar

[2] Seam Welded Tubing

[3] Inserts Machined From Ti-6Al-4V Bar

[4] See Figure 9 for Sketches of these joints

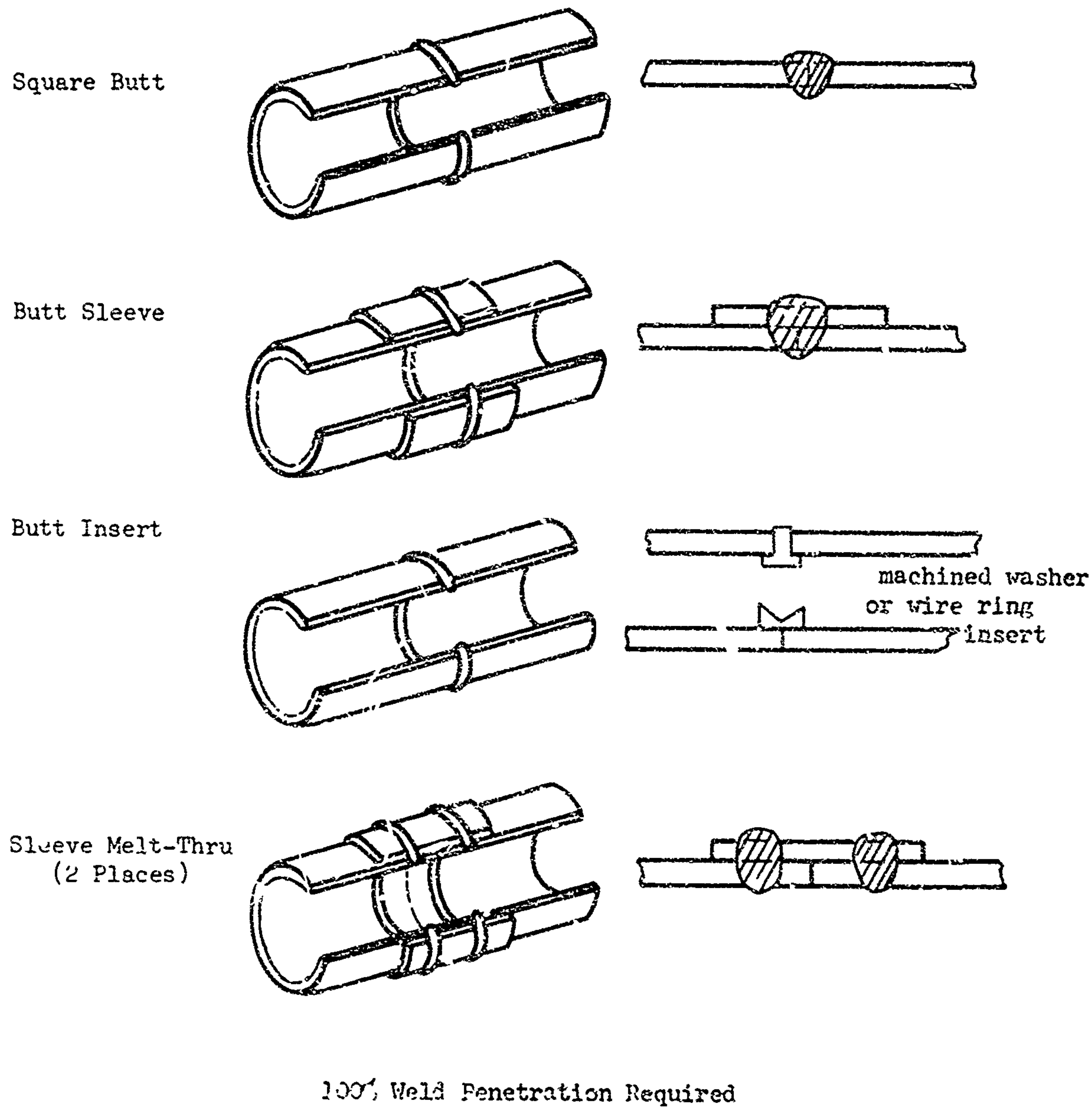


Figure 8. Types of Weld Joints, In-Place Tube Welds

Table J Summary – Tensile Results, .25" Thick Titanium Alloy

MATERIAL	SPECIMEN TYPE	WELDING PROCESS	FILLER WIRE	STRESS (KSI) ULT.	STRESS (KSI) YIELD	ELONG (%) 1 IN	ELONG (%) 2 IN	REDUCED AREA (%)	JOINT EFFICIENCY (%)
Ti-4Al-3Mo-1V (1)	Base Metal			138.5	124.7	17.0	11.3	17.6	----
	Long. Weld	DGTA (2)	None	146.5	130.8	4.6	3.2	8.6	100
	Trans. Weld	DGTA	None	136.4	127.0	0.4	2.4	18.8	98

\# Data show average of 5 specimens

(1) Beta Annealed 1900°F, 30 Min., Air Cooled
Solution Treated 1715°F, 30 Min., Water Quenched
Aged 1150°F, 8 Hrs. Plus Hot Flattened 2 Hrs., Air Cooled
Weldment Stress Relieved 1150°F, 30 Min., Air Cooled

(2) Dual, Gas Shielded Tungsten Arc

III Description of Technical Progress (continued)

11 AIRFRAME STRUCTURE

1100 Airframe Structure – General

11001 TITANIUM ALLOY DEVELOPMENT

Test specimen elevated temperature exposures for determination of metallurgical stability of Ti-6Al-4V and Ti-4Al-3Mo-1V are continuing. Approximately 8000 hours exposure at 450F/25 ksi has been accumulated for β -STA-1250 Ti-6Al-4V and β -STA-1150 Ti-4Al-3Mo-1V material. Fracture toughness stress corrosion, and tensile testing will be conducted after exposure for 10,000 hours. Duplex annealed and STA-1250 Ti-6Al-4V notch bend blanks have been prepared for 1000 hour and 2500 hour exposures to 450F/25 ksi and 650F/25 ksi. Baseline data have been reported. Thin film electron microscopy has been used to study several β -STA-1250 Ti-6Al-4V exposure specimens. No microstructural changes were apparent after exposures up to 5000 hours.

Fracture testing of various thicknesses and conditions of Ti-6Al-4V is continuing. The testing of 0.040, 0.125 and 0.150-inch thick material in mill and duplex annealed conditions is in progress. Test specimens of 0.150-inch thick material in the STA-1000 and STA-1250 conditions have been fabricated and heat treated. In addition, specimens of 0.188-inch thick material in the β -STA-1250 and STA-1250 conditions are being fabricated. A sheet of 0.250-inch thick material is being prepared for heat treatment to the β -STA-1000 and β -STA-1250 conditions.

11002 HIGH STRENGTH STEEL EVALUATION

With the exception of the fatigue test of the 9Ni-4Co, Model 720 torsion link forging, all scheduled testing has been completed. The forging had completed 75,000 cycles of simulated service loads when the test fixture failed. The fixture is now being repaired.

11004 STRUCTURAL DESIGN CRITERIA

(1) Fatigue Testing

Two specimens, representing full scale portions of wing structure, are being fatigue tested at a maximum stress of 60 ksi and R = .05. A Ti-6Al-4V three stiffener and skin panel, fabricated with A-286 squeezed rivets, has sustained 110,000 cycles without failure in either the skin or the skin flange of the stiffener. Three cracks have occurred in the free flanges of the stiffeners where they are attached to the simulated rib chord, the earliest being at about 56,000 cycles. The local flange pad-up at these locations was limited to 33 percent by the size of available extrusions and does not satisfy the fatigue criteria of 50 percent pad-up. Testing is continuing.

11004 Structural Design Criteria (continued)

A Ti-6Al-4V wing stiffener runout panel is in test. First crack occurred at 12,500 cycles in the stiffener trim, and additional cracks have occurred in the skin and the skin flange of the stiffener. 18,900 cycles have been accumulated to date on this initial design concept.

Fatigue testing of baseline specimens is continuing. Results of recent tests for evaluation of fasteners, sheet thickness, and pre-test thermal exposure are presented in Figs. 9 and 10.

(2) Fatigue Analysis

Document D6A10463-1, "Fatigue Analysis and Test Loads - B-2707 Outer Wing Panel Fatigue Test Box Number 1" has been released. This document describes the fatigue analysis and presents the initial definition of the test loads and temperatures for the first of the three full scale wing box fatigue test specimens.

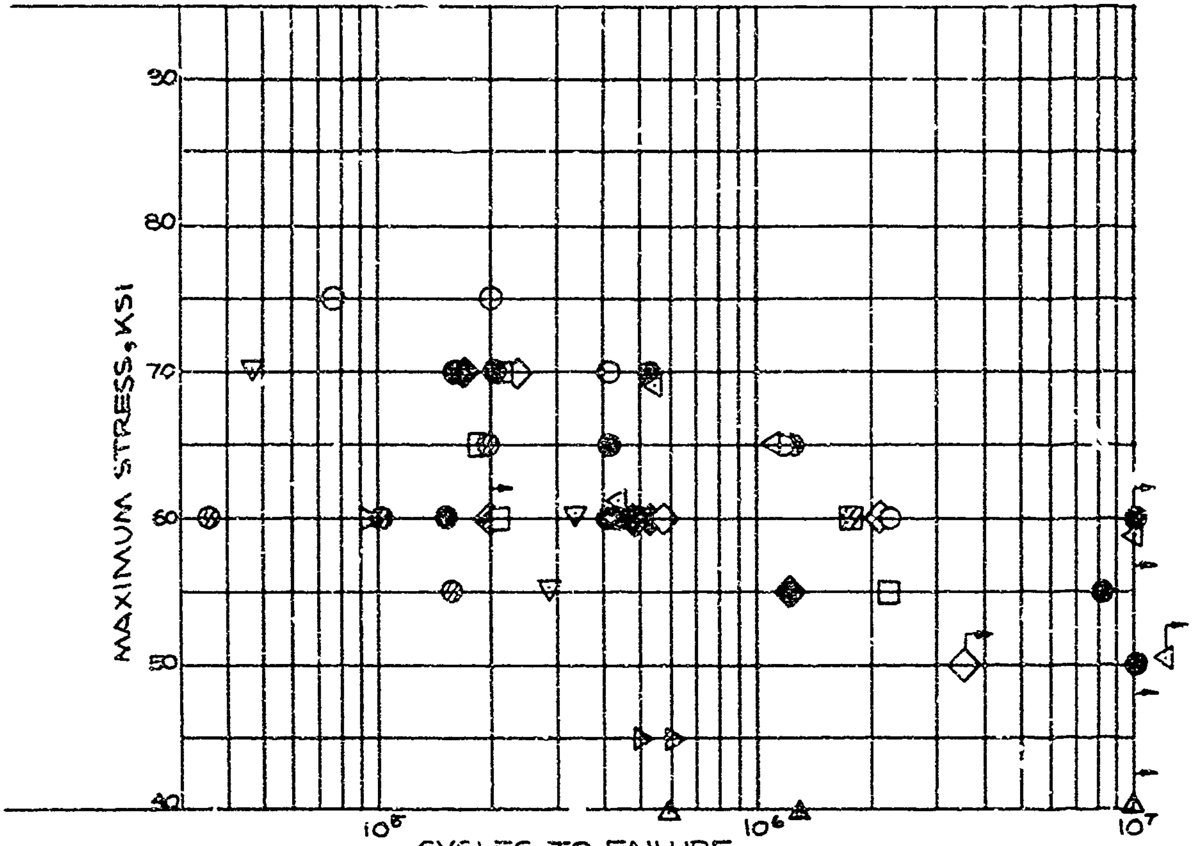
(3) Fuselage Failsafe Testing

Three additional crack growth tests and two puncture tests have been completed on the Ti-6Al-4V failsafe verification test panel installed on the full scale fuselage test section (Ref. D6A18110-4, p. 130).

The third crack growth test consisted of a series of cracks in the 0.032 gage Ti-6Al-4V Cond. I skin material at a skin splice. Figure 11 shows the crack configuration and the crack growth history. After 1000 cycles failed to produce any detectable crack growth, the center crack was extended by sawcutting to 7.53 inches. Testing was discontinued at 6460 cycles with a final center crack length of 7.66 inches and no indication of growth from any of the end cracks.

The fourth crack growth test was conducted in the 0.050 skin panel without tear straps. The crack growth history is also shown in Fig. 11. The crack was extended by pressure cycling from an initial length of 8 inches to a length of 29.6 inches, at which point slow crack extension under constant pressure was obtained and testing was discontinued. At several earlier points during the extension of the crack, maximum pressure was maintained for 5 minutes without crack extension.

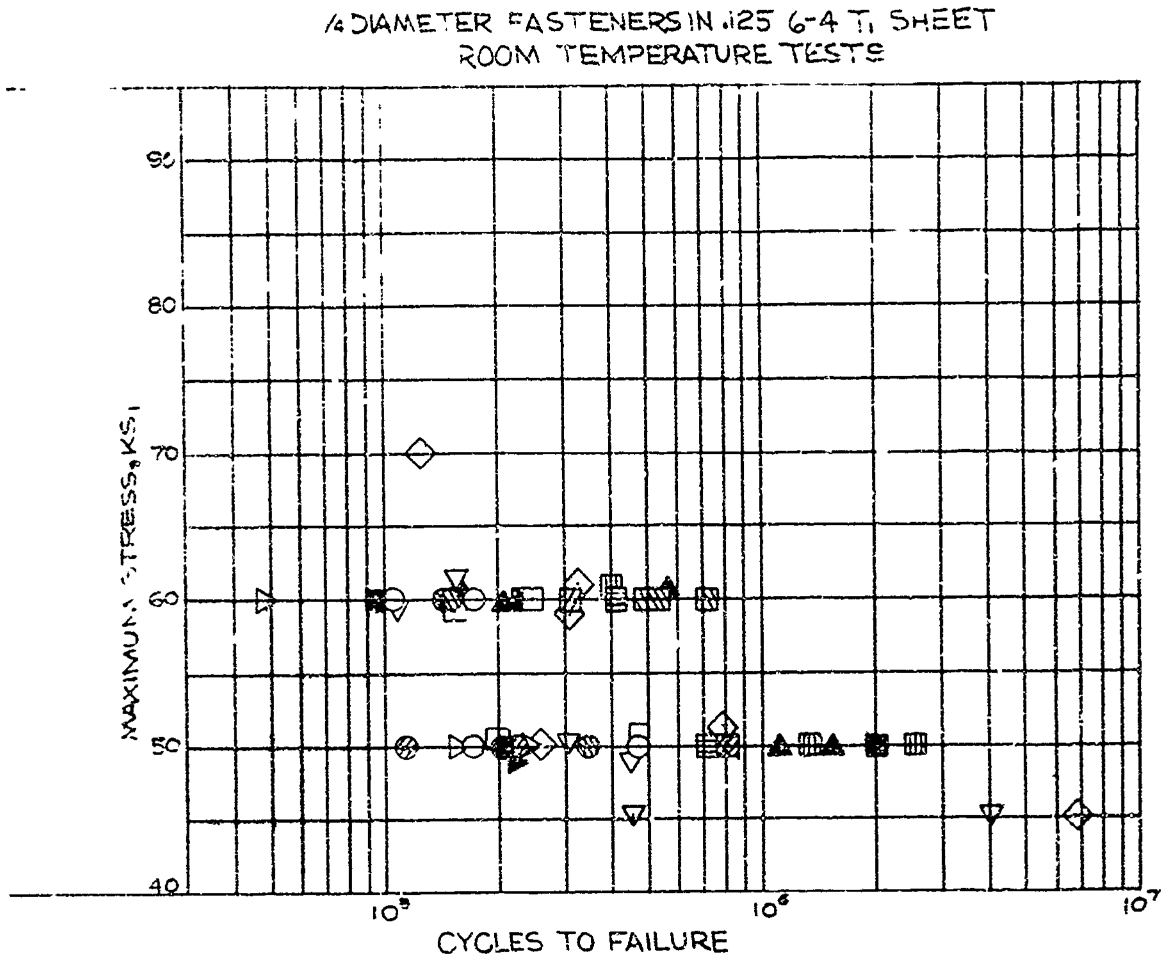
The fifth crack growth test was conducted with both skin and a tear strap damaged. An initial saw cut 8 inches in length was made in the 0.032 skin adjacent to a tear strap in such a manner that the cut passed through a rivet location on the tear strap. The tear strap was also cut at the skin crack location in such a manner that approximately 0.1-inch of the 0.37-inch wide tear straps was intact. The



TITANIUM 8-1-1 BASELINE SPECIMEN WITH A-286 RIVETS
ROOM TEMPERATURE TESTS

SYMBOL	GUAGE	RIVET DIA.	PRETEST EXPOSURE	PRELOAD AFTER EXPOSURE	R
⊙	.040	1/8	NONE	NONE	.06
●	.040	1/8	500 HRS @ 500°F	NONE	.06
⊘	.040	1/8	500 HRS @ 500°F	85 KSI	.06
⊡	.050	1/8	500 HRS @ 500°F	NONE	.06
▨	.050	1/8	500 HRS @ 500°F	85 KSI	.06
▷	.090	3/16	500 HRS @ 500°F	NONE	-.25
△	.188	5/16	500 HRS @ 500°F	NONE	.06
▲	.188	5/16	500 HRS @ 500°F	80 KSI	.06
◇	.188	1/4	NONE	NONE	.06
◆	.188	1/4	500 HRS @ 500°F	NONE	.06
◈	.188	1/4	500 HRS @ 500°F	80 KSI	.06
▽	.025	5/32	500 HRS @ 500°F	NONE	.06
◁	.025	1/8	500 HRS @ 500°F	NONE	.06

Figure 9. Gage Effects on Baseline Specimen Fatigue Life



SYMBOL	FASTENER	PRETEST EXPOSURE	PRELOAD AFTER EXPOSURE	R	6-4 CONDITION
○	TAPER-LOK	NONE	NONE	.06	ALL-B
●	TAPER-LOK	500 HR @ 500°F	NONE	.06	ALL-B
⊘	TAPER-LOK	1000 HR @ 500°F	NONE	.06	α-B
⊘	TAPER-LOK	500 HR @ 500°F (WITH 40 KSI)	NONE	.06	α-B
▷	HI-LOK	NONE	NONE	.06	ALL-B
▶	HI-LOK	500 HR @ 500°F	NONE	.06	ALL-B
□	A-286 RIVET	NONE	NONE	.06	ALL-B
■	A-286 RIVET	500 HR @ 500°F	NONE	.06	ALL-B
▨	A-286 RIVET	1000 HR @ 500°F	NONE	.06	α-B
▧	A-286 RIVET	500 HR @ 500°F (WITH 40 KSI)	NONE	.06	α-B
▤	A-286 RIVET	1000 HR @ 500°F (WITH 40 KSI)	NONE	.06	α-B
▥	A-286 RIVET	2000 HR @ 500°F	NONE	.06	α-B
▲	A-286 RIVET	500 HR @ 500°F	85 KSI	.06	α-B
◇	6-4 RIVET	NONE	NONE	.06	α-B
▽	6-4 RIVET	NONE	NONE	.25	α-B

Figure 10. Baseline Specimen Test Results

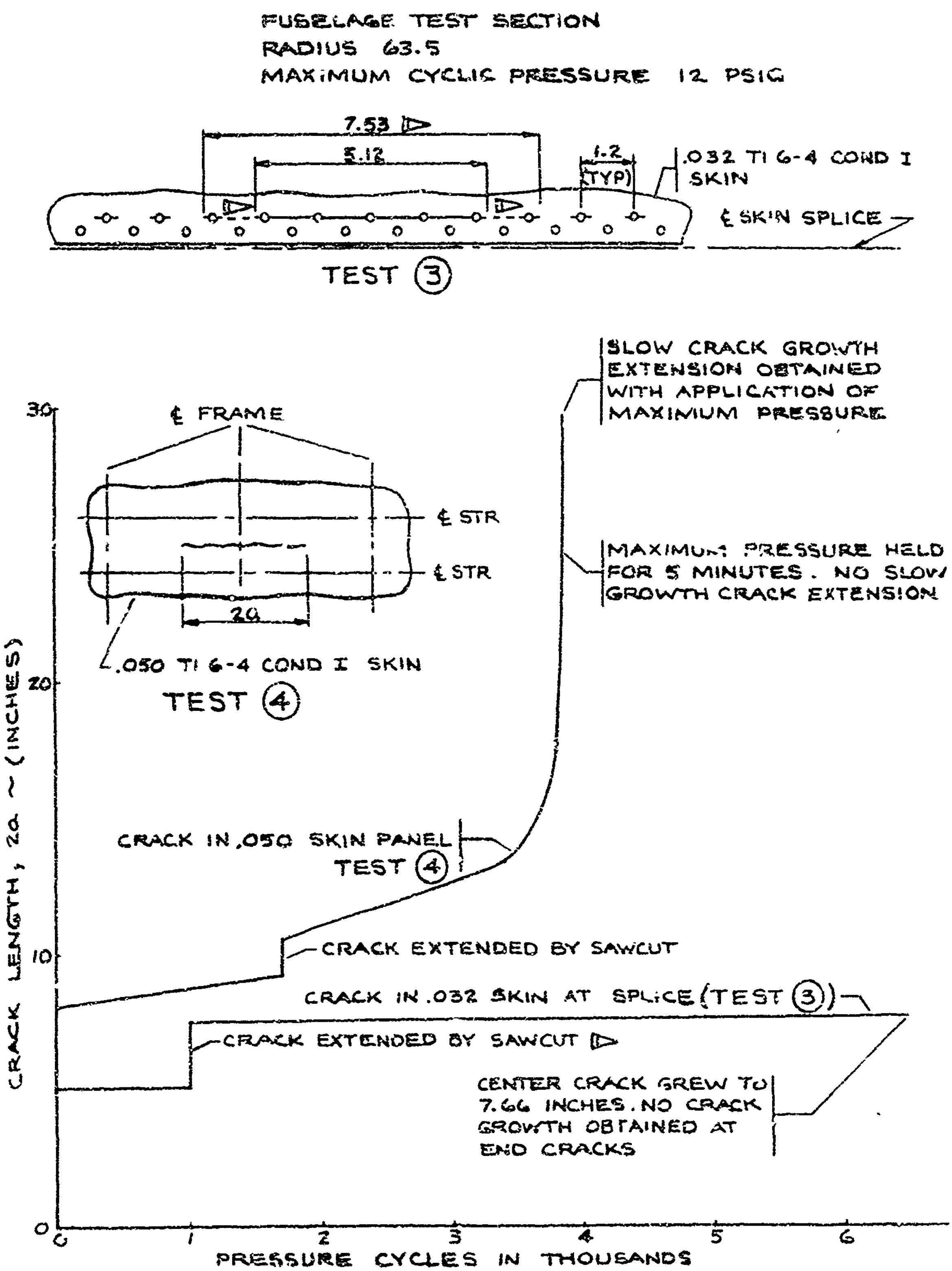


Figure 11. Fuselage Crack Growth Tests

11004 Structural Design Criteria (continued)

crack configuration and crack growth history are shown in Fig. 12. After 400 cycles, the lefthand side of the crack grew into the rivet hole at the remaining dual tear strap and was arrested. At approximately the same time, the partially severed tear strap failed. The crack length at this time was 10.43 inches. Cycling was continued until the righthand side of the crack grew into a rivet hole at the first tear strap of the adjacent frame station and was arrested. An additional 87 cycles produced no growth from either end of the crack, and testing was discontinued.

The first puncture test was conducted on the 0.050 gage skin panel. Damage from the 12-inch wide blade was confined to the punctured area.

The second puncture test was conducted on the 0.032 gage skin panel. The 12-inch wide blade was fired into the center of a skin panel bordered by stringers and tear straps. Damage was confined within the local area of the panel.

Damage resulting from these tests is shown in Figs. 13 and 14.

11005 LOADS & CRITERIA

(1) Speed Margin

The simulator study to evaluate the B-2707 operational limits is continuing with Boeing and airline pilots participating in the program. The complete results will be reported in Document D6A10459-1 to be released in December.

(2) Dynamic Loads - Taxi

Analytical studies of the B-2707 airplane taxiing over runway 25L at the J. F. Kennedy Airport have been completed. These analyses consider taxi runs at various constant velocities for both hard (proposal configuration) and soft landing gear suspensions. The soft suspension incorporates a two-stage airstroke on each main gear and a 6-inch stroke extension on the nose gear. The reduction in incremental vertical acceleration at the pilot station (Δ n) associated with the soft gear system is shown in Fig. 15 where the maximum Δ n decreases from 2.5 g to 0.62 g. Actual measured values for the FAA's Boeing 720 airplane obtained during taxi runs over the identical runway are included for comparison. The B-2707 values were calculated for the maximum gross weight airplane and therefore represent the most severe taxi condition.

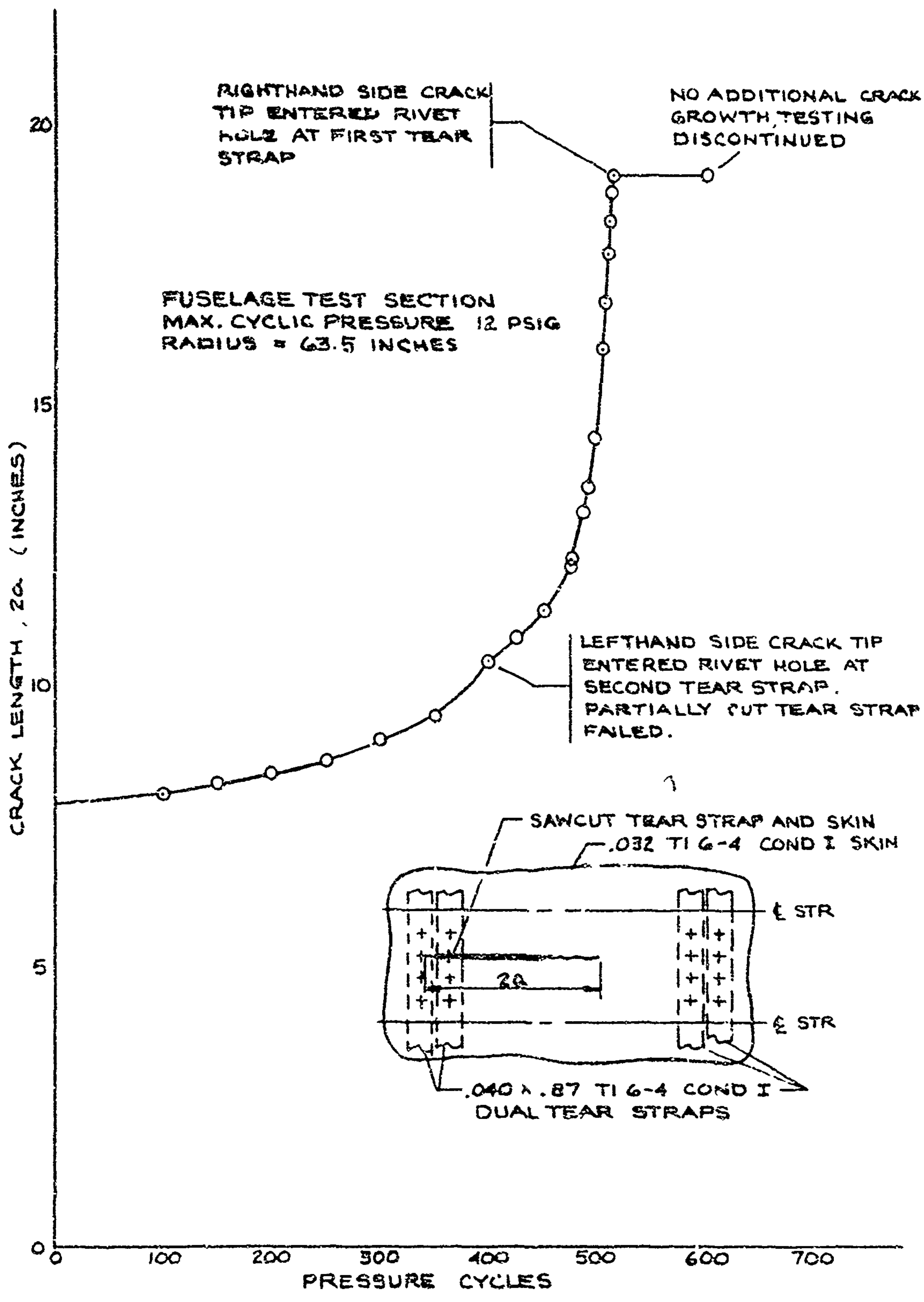


Figure 12. Fuselage Test Panel No. 4, Crack Growth History Test No. 5

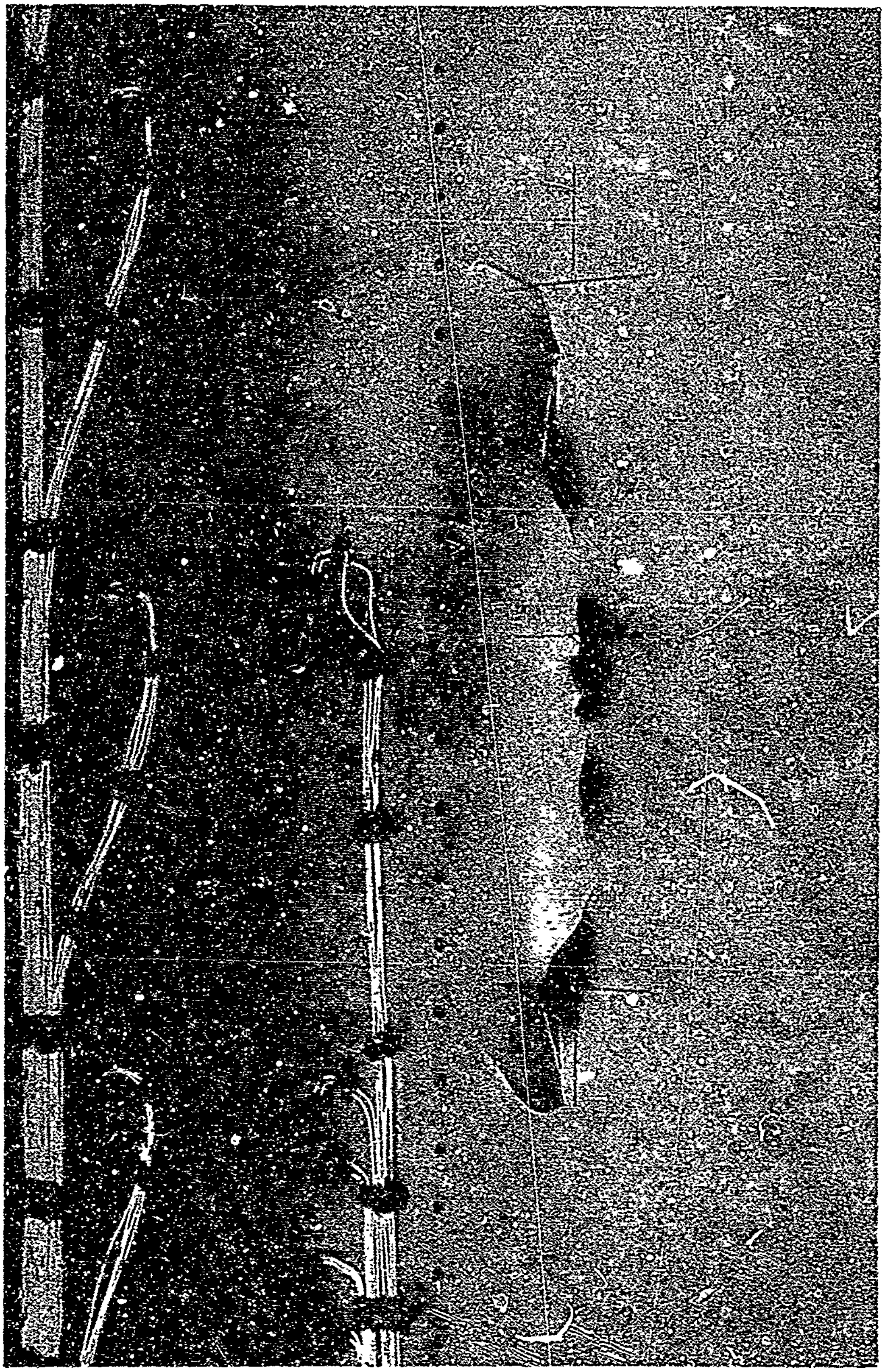


Figure 13. Puncture Test on .050 Gage S[illegible] Panel

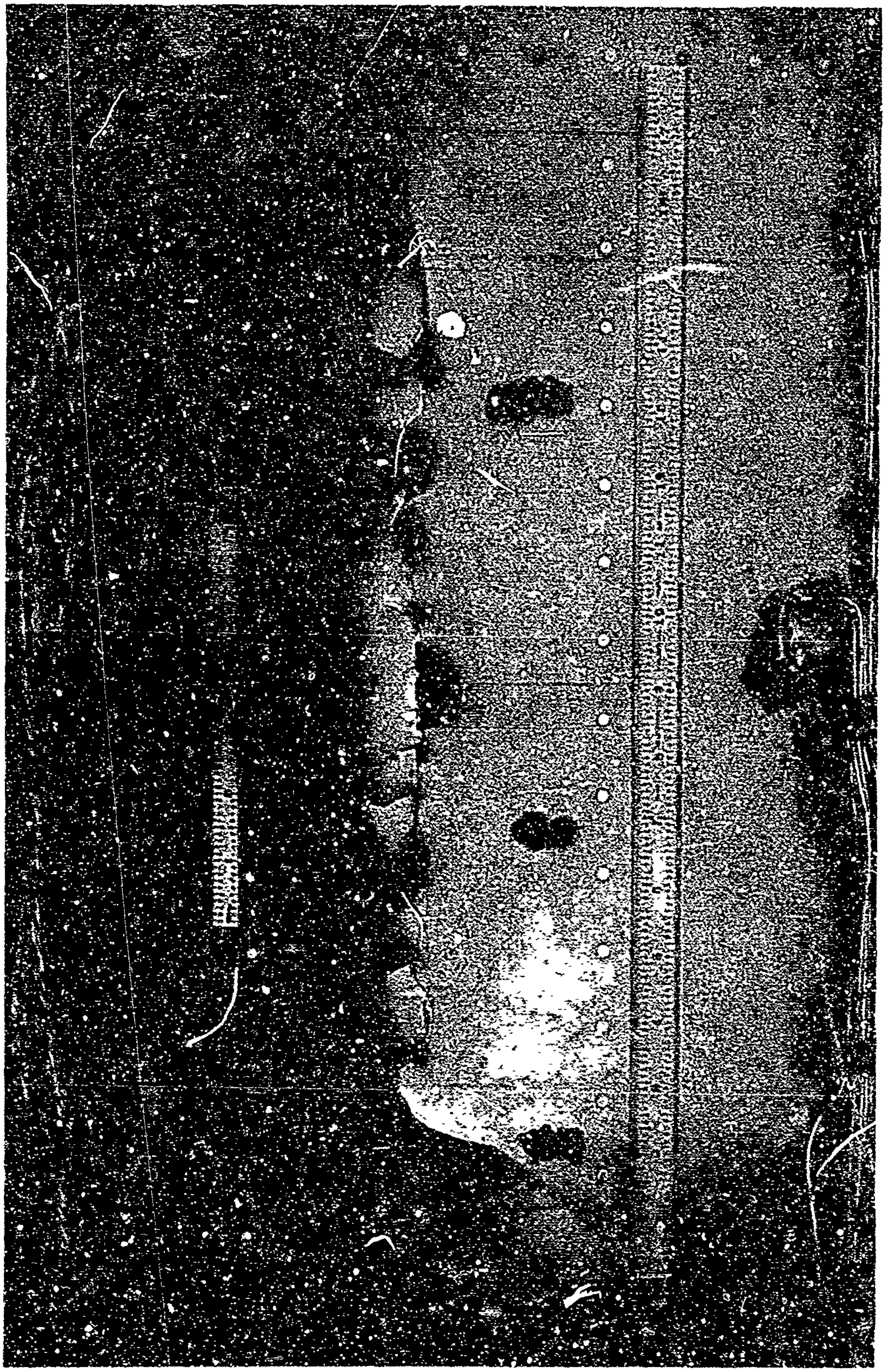


Figure 14. Puncture Test on .032 Gage Skin Panel

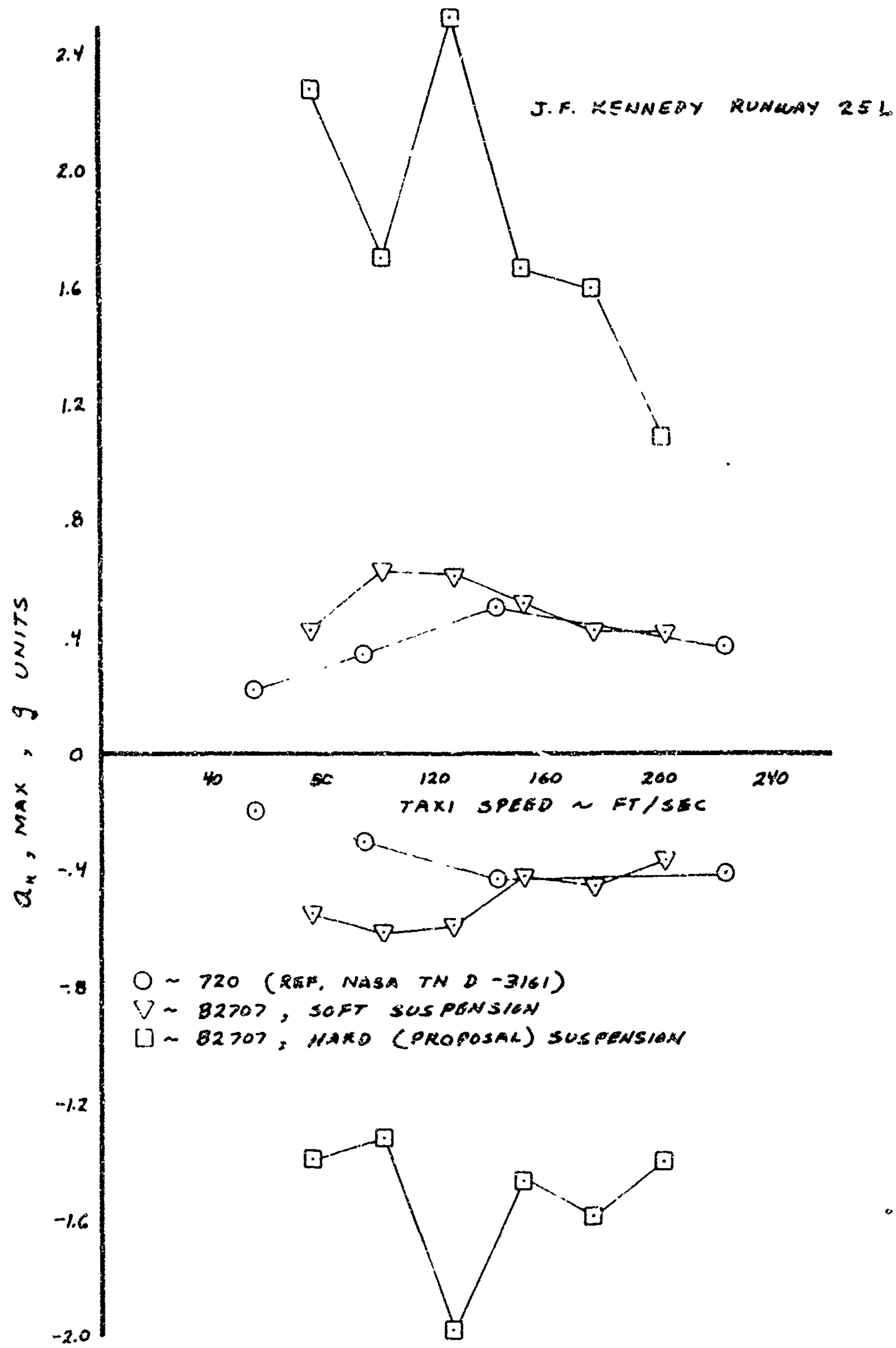


Figure 15 Vertical Incremental Acceleration at the Pilot Station During Taxi

III Description of Technical Progress (continued)

11006 FLUTTER

A 1/20-scale flutter model of the Boeing SST was tested in the Langley Research Center 16-foot Transonic Dynamics Tunnel during October, 1966. The full-span model shown in Fig. 16 dynamically-scaled the major components of the airplane (i.e., wings, fuselage, and horizontal and vertical tails). The model was flown in the wind tunnel on a cable-support system, developed at Langley, which provided virtual freedom of flight in five axes with significant restraint only in the direction of flow. Remotely-controlled horizontal tail trailing edge control surfaces were provided for trimming the model in the tunnel. Left and right control surfaces were differentially controlled for roll trim.

The model provided for wing sweep positions of 72° and 42° sweep angle. Minimum flying weight condition for the B-2707 with G.E. engines was represented. The wing to stabilizer interlock was not provided.

Figure 17 shows the scaled 1.2 V_D boundaries for the 72° and 42° wing positions through the transonic speed regime. The test points shown were the upper limits achieved with each sweep condition during the test. The diagonal lines leading up to the maximum test points represent the actual dynamic pressure - Mach number test profile for each of the points presented. Normal procedure called for increase of q and M simultaneously, approximately along a constant total pressure line, once the tunnel had been pumped down to an appropriate starting pressure. As shown in the graph, the configuration exceeded the required flutter boundaries without encountering flutter in the transonic speed range.

1101 Wing

(a) Design

Detail design in the pivot area of the leading edge and trailing edge of the wing was accomplished to accommodate the 20 degree wing sweep angle of the B-2707-100 configuration as shown in Document V1-B2707-5.

(.) Tests

(1) Wing Box Failsafe Tests

The second failsafe test has been conducted on the Ti-6Al-4V failsafe designed lower surface of the full scale wing box test section, Fig. 18. The test simulated a broken stringer. The crack growth history for this test is shown in Fig. 19 with the final panel damage shown in Fig. 20.

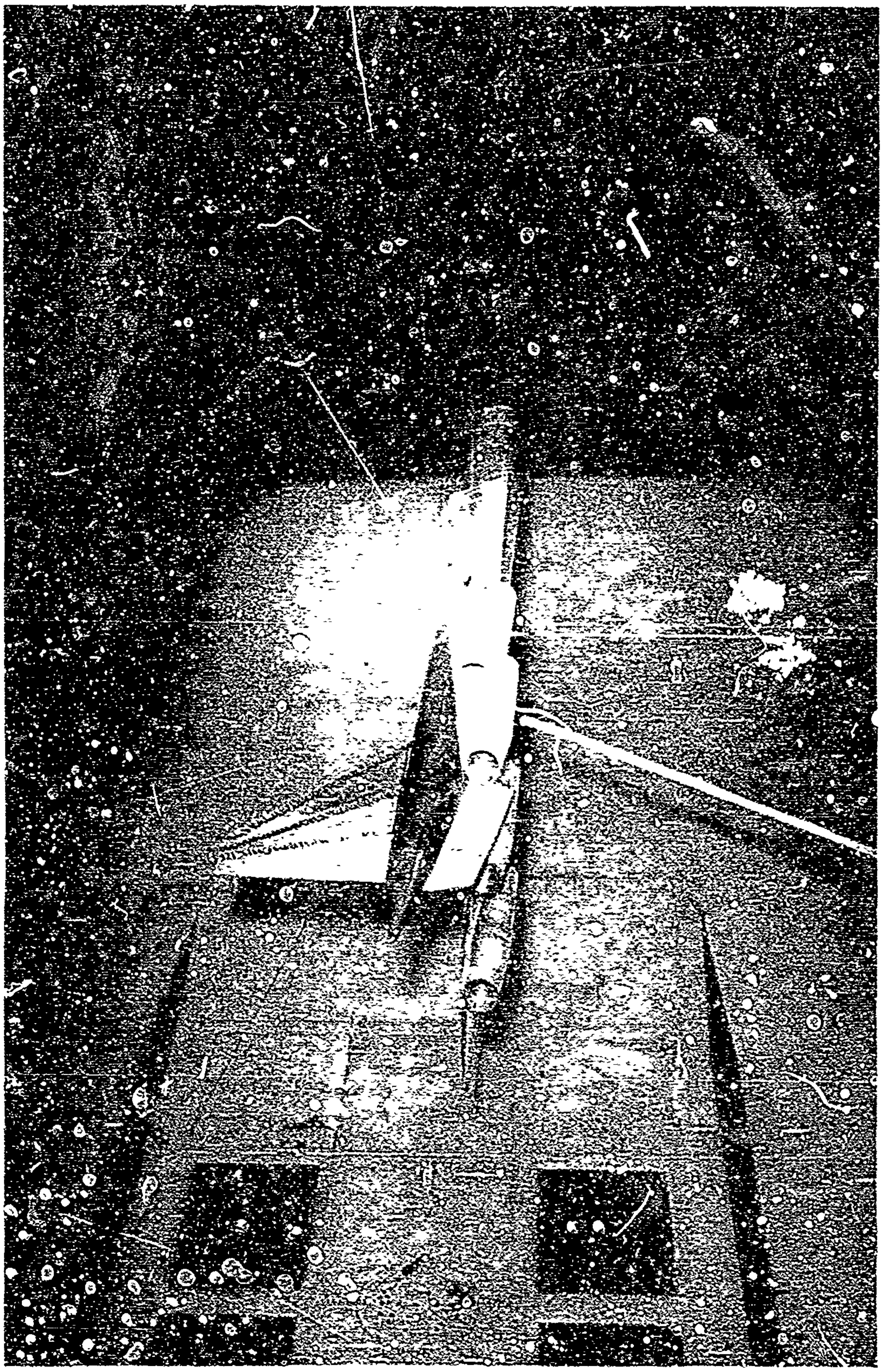


Figure 16. Full Span Flutter Model

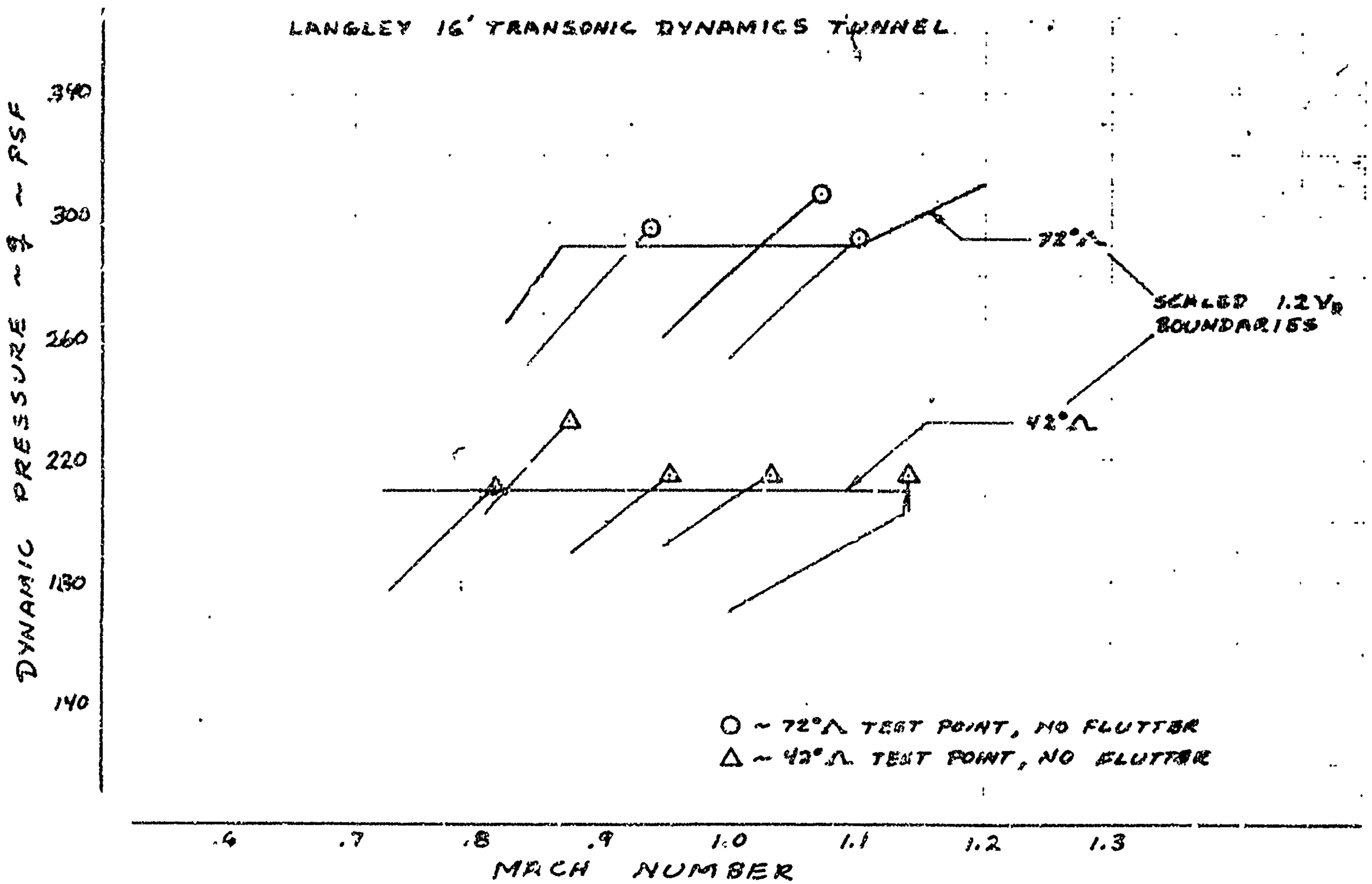


Figure 17. Transonic Flutter Model Test Data

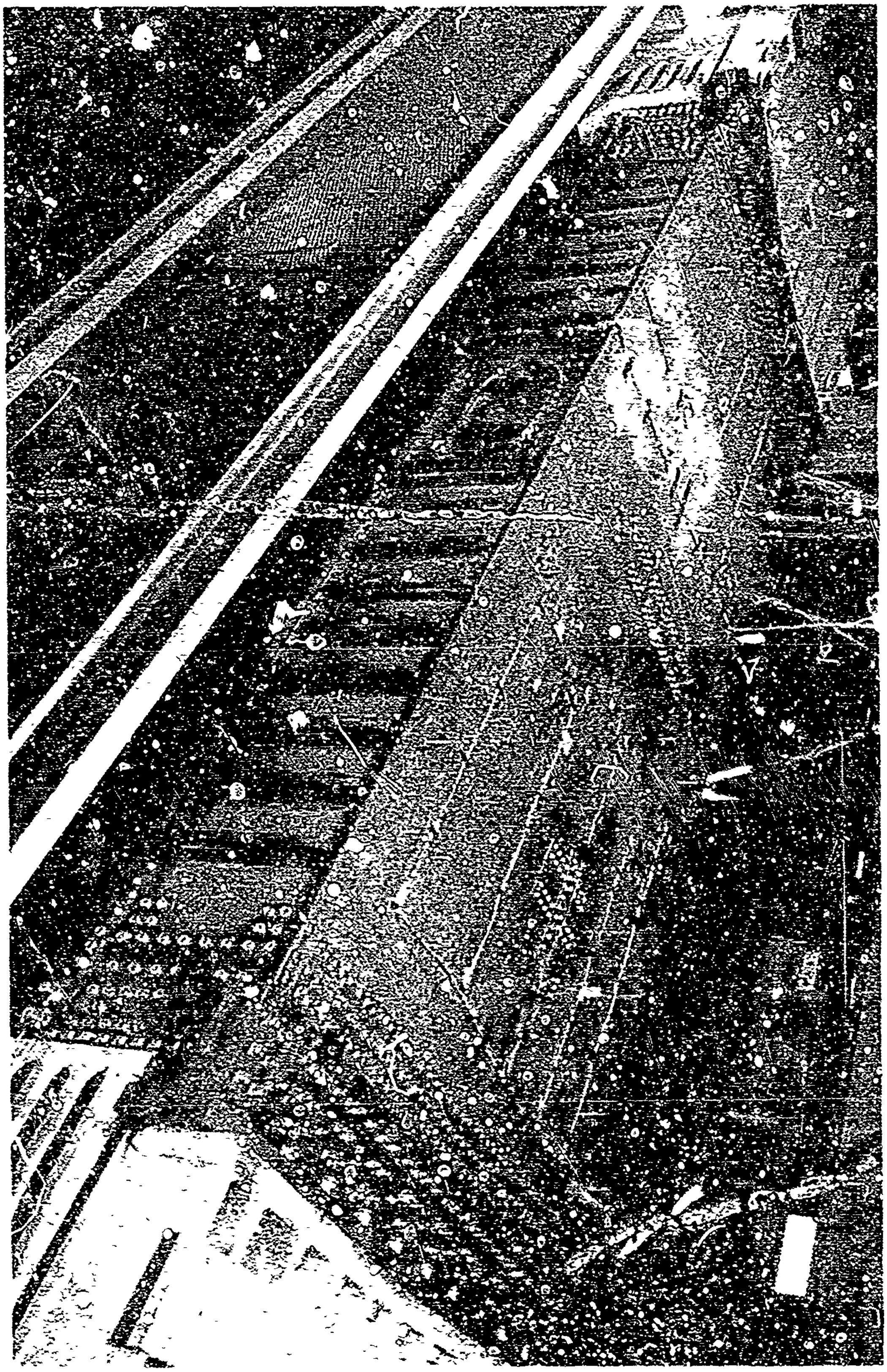


Figure 18. Outboard Wing Box Test Assembly

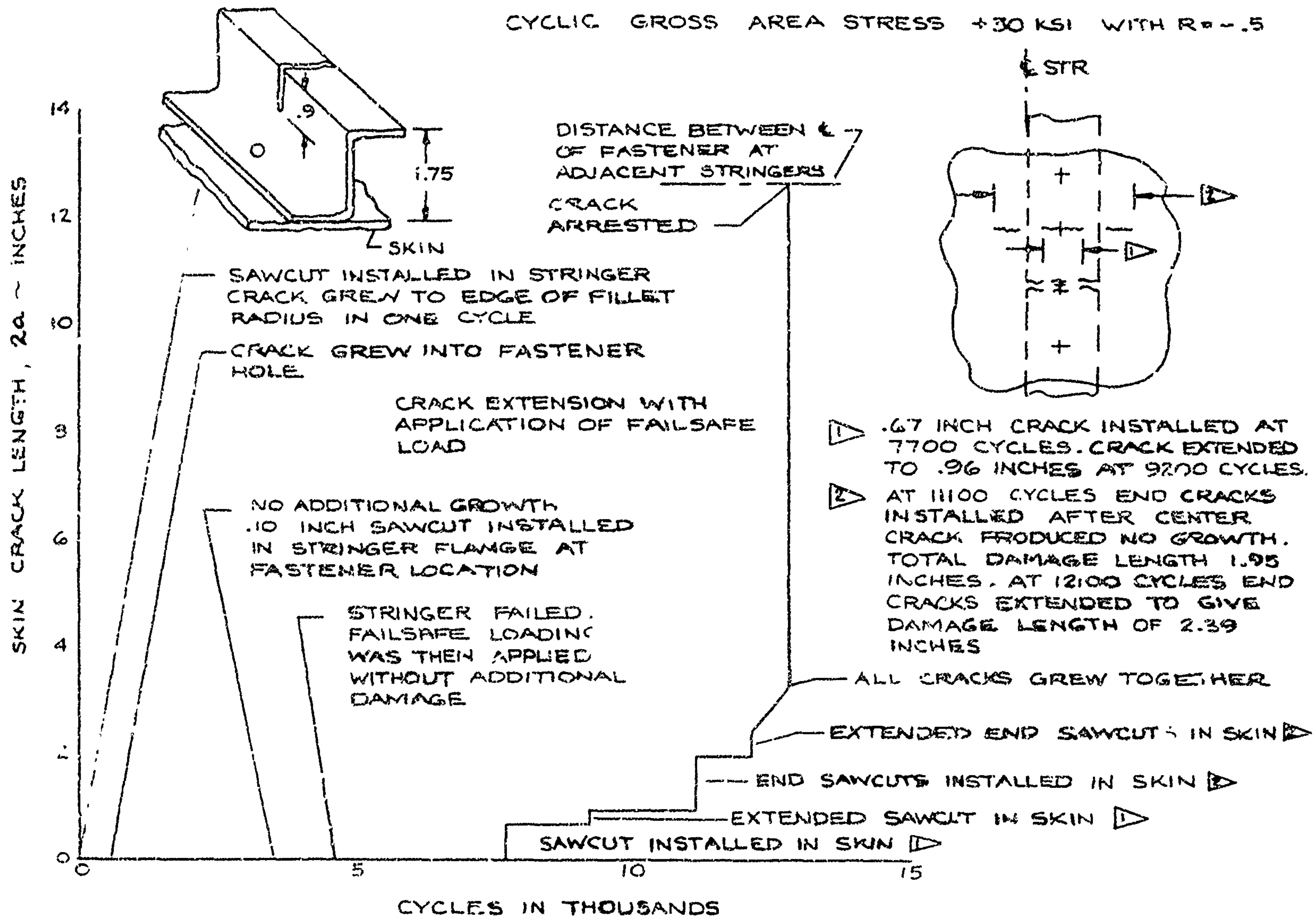


Figure 19. Wing Box Crack Growth History

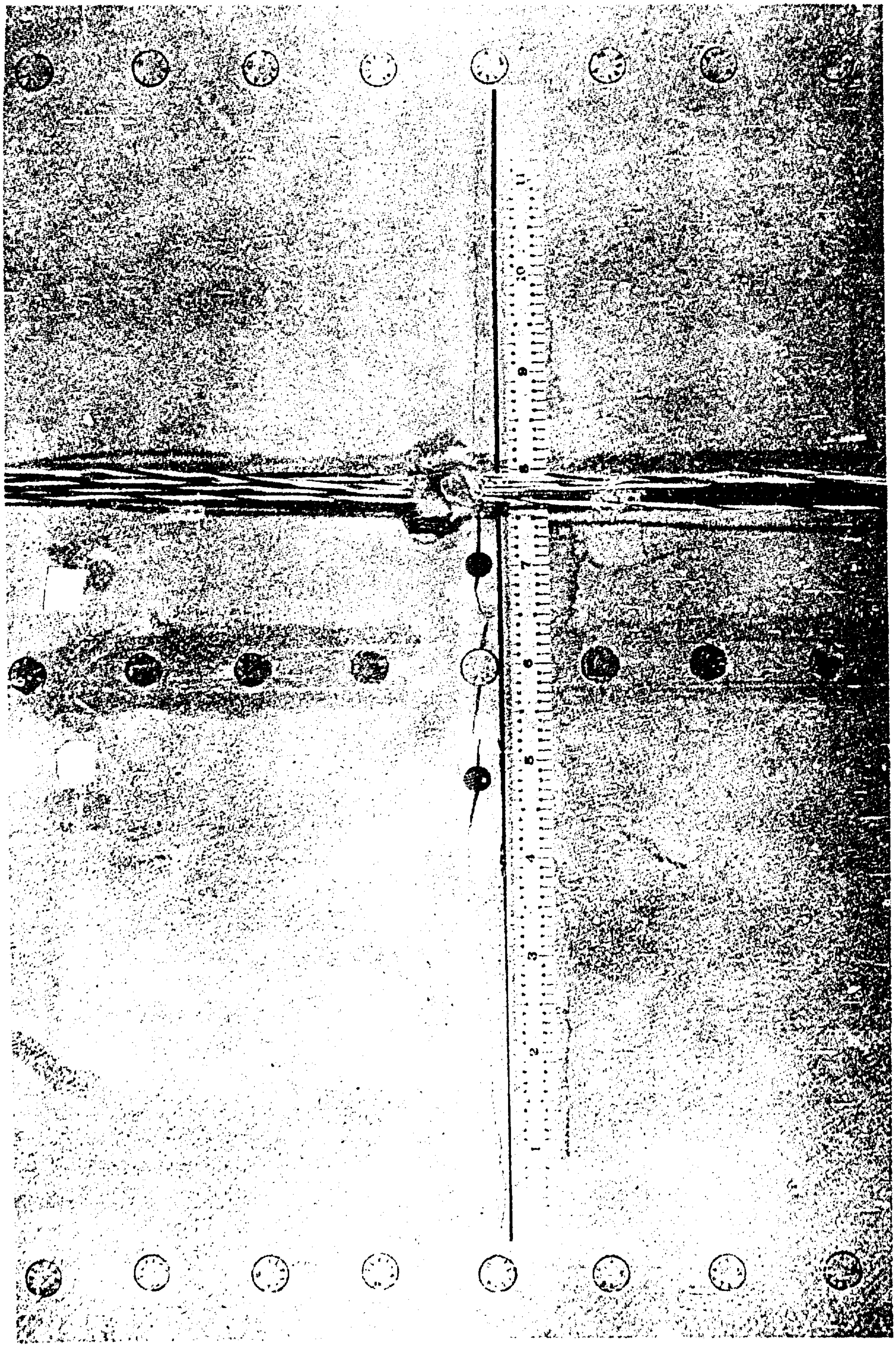


Figure 20. Wing Box Fail Safe Crack

III Description of Technical Progress (continued)

1101 Wing (continued)

The broken stringer configuration was simulated by installing a saw cut in the stringer. The crack extended the remaining depth of the vertical web of the stringer on the first load application. At 540 cycles, the crack had extended into a fastener location and was arrested. When 3500 cycles produced no additional growth, a 0.10-inch saw cut was made in the stringer and complete stringer failure was obtained at 4600 cycles. With the stringer completely broken, a design failsafe load was applied without incident.

After 7700 cycles had not produced a skin crack, a 0.67-inch long saw cut was made in the skin at the first fastener away from the broken stringer location. At 9200 cycles there was no indication of crack growth and the saw cut was enlarged to 0.97 inches. At 11,100 cycles, saw cuts were made at either end of the skin crack. Total damage length at this time was 1.95 inches. The damage length was enlarged to 2.39 inches at 12,100 cycles when no visible growth was obtained. At 12,750 cycles, all cracks had joined together to form one crack 3.25 inches in length. A design failsafe load was then applied. With the application of the failsafe load, the skin crack extended into fastener locations at the adjacent stringers and was arrested.

The test has demonstrated that the number of cycles required to extend cracks is more then ample to allow detection by inspection and that failsafe loads can be sustained on severely damaged configurations without producing catastrophic effects.

The test section is being repaired for additional testing as outlined in V2-B2707-9.

(2) Test Hardware - Wing Fatigue Boxes

The first wing fatigue test box has been received from NORAIR (Fig. 21), and is being prepared for the heat soak cycle of the room temperature test. Start of heat soak is scheduled for mid-December.

(3) Test Hardware - Wing Pivot Assembly

The outboard pivot segment has been received from NAA (Fig. 22), and is awaiting completion of the inboard segment (Fig. 23) for the final assembly operation. Initial tests will measure the no-load bearing friction and are scheduled to start at the end of December.

1104 Fuselage

Structural investigations were conducted and design support was provided for the development of the configuration refinements and improvements resulting in the B-2707-100. Detailed fuselage structural refinement of the configuration is continuing.

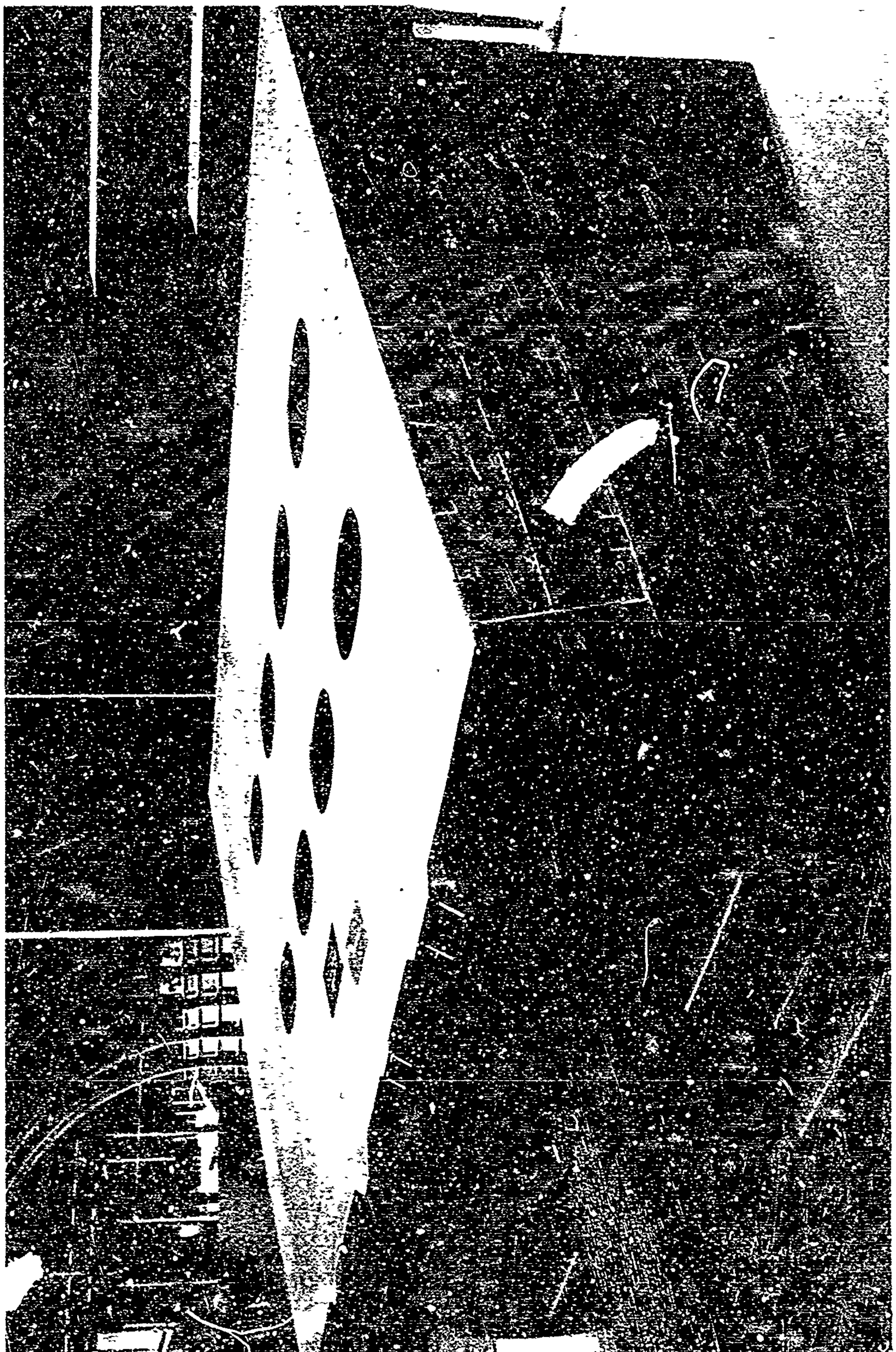


Figure 21. Outboard Wing Fatigue Test Box

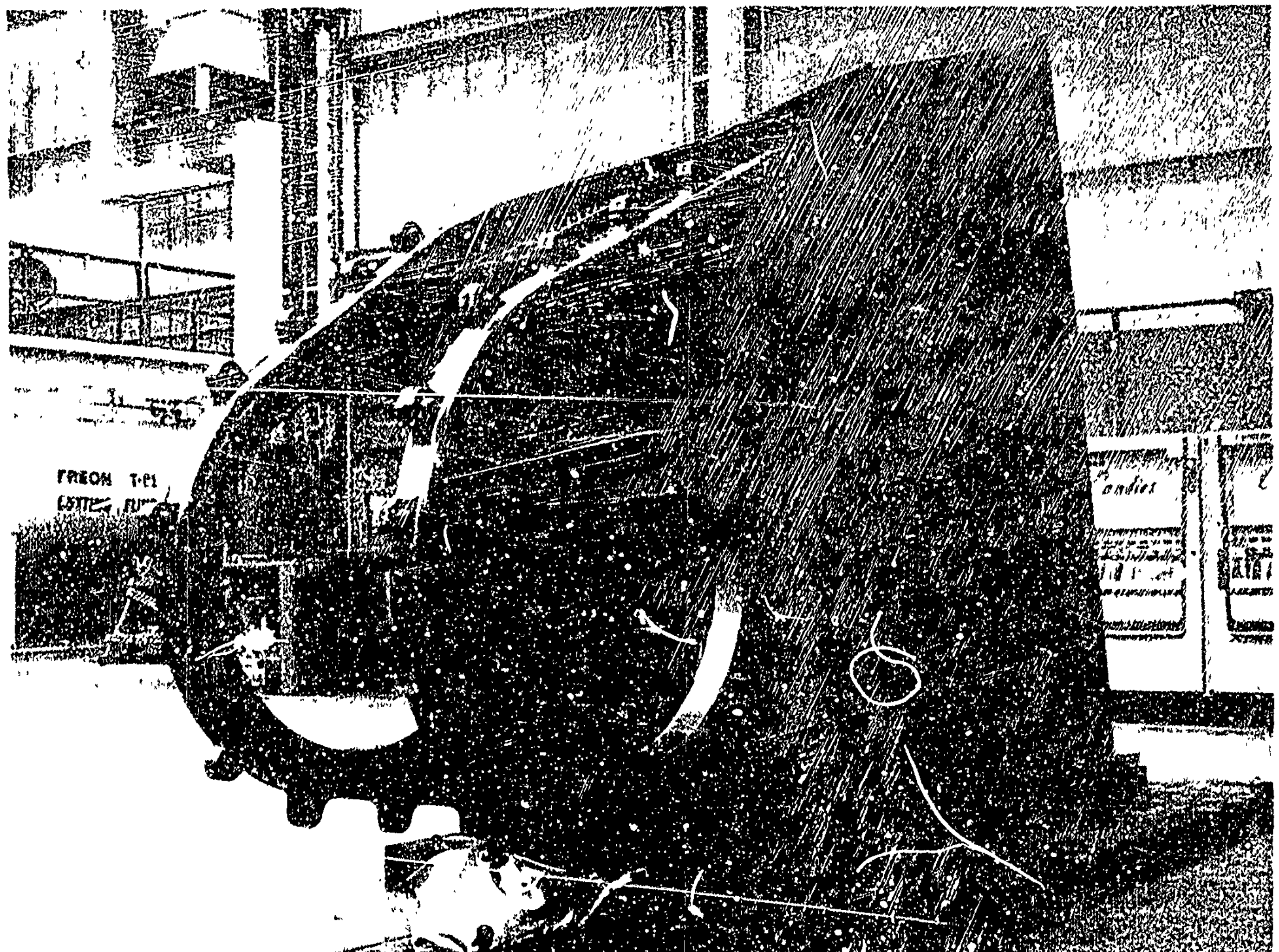


Figure 22. Wing Pivot Test Assembly -- Outboard Portion

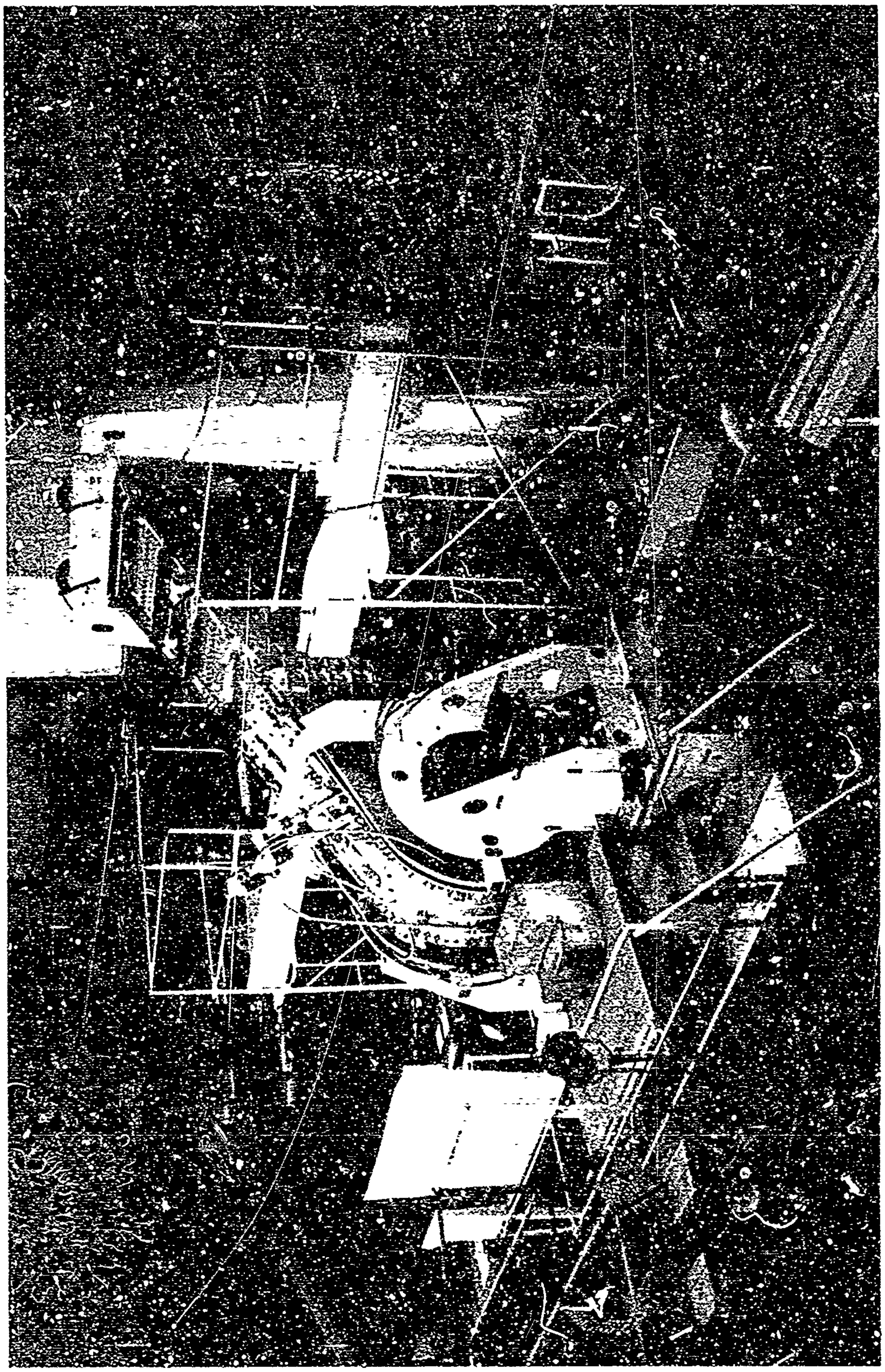


Figure 23. Wing Pivot Test Assembly — Inboard Portion

1104 Fuselage (continued)

Fabrication of the Section 43 full sized test cab shown in Fig. 24 is progressing satisfactorily. Use of mathematical loft has provided excellent fit-up between parts. Reduction in the number of detail parts by use of machined sill and post structure has simplified assembly. External skins are currently being installed.

1106 Landing Gear

(1) Wheel and Brake Specifications

A preliminary wheel and brake specification has been released and sent to the Wheel and Brake Vendors. Vendors will submit proposals based on this specification, and proposals will be evaluated for selection of vendor.

(2) Wheel Well Cooling

Tests have been initiated to determine wheel well cooling requirements. The objective is to determine the optimum combination of cooling airflow rate, airflow distribution, and insulation.

The test assembly consists of a 367-30 landing gear (strut, truck, tires, and wheels) mounted in a simulated B2707 main outboard wheel well. Electric heating blankets installed above and below the wheel well simulate the aerodynamic heating profile during a design mission including a two hour cruise at 2.7 Mach.

Tests to date indicate that the design cooling airflow rate will maintain acceptable maximum tire temperatures ($\leq$ 180°F) without the addition of insulation. Structural polyimide honeycomb now provides the insulation from the aerodynamically heated titanium skin.

1107 Power Plant Structure

The method of supporting the General Electric GE4/J5P engine on the B-2707-100 is shown in V1-B2707-5, Fig. 2-29. This concept is the same as proposed to support the P&WA JTF17A-21B engine on the basic B-2707 (P&WA)airplane. (See V2-B2707-6-2, Fig. 3-49). On the B-2707-100 airplane, the General Electric engines are located on the horizontal stabilizer 60 inches aft of the position proposed for the B-2707 (GE) configuration, which resulted in the selection of this type of mount structure. The use of this support beam attached to the lower surface of the horizontal stabilizer for both engines will minimize the structural differences required to install the alternate engines.

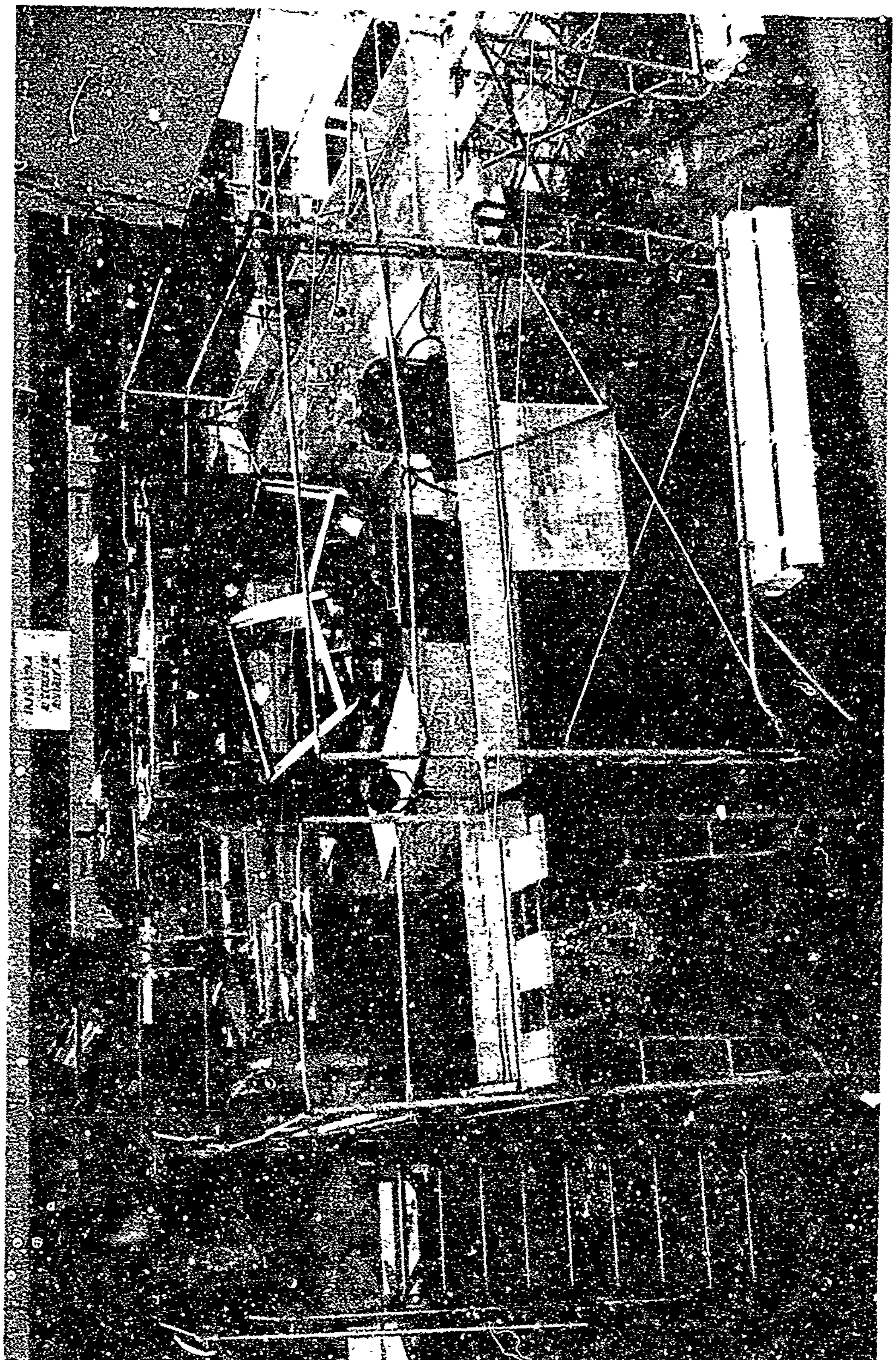


Figure 24. Section 41 Test Cab

III Description of Technical Progress (continued)

1108 Empennage

(1) Design

For the B-2707-100 airplane, a design was developed which allowed increasing the elevon area to 227 square feet per side. The elevon is supported on a beam which is an extension of the mid spar of the stabilizer. Inboard and outboard bearings provide support and allow elevon motion. The elevon is actuated by an arm forward of the support beam. The actuator is installed within the stabilizer which has been thickened in this area. Fig. 2-26 of V1-B2707-5 shows these details.

(2) Testing

Assembly of the empennage test structure has been completed and mounted in the test fixture. The Evener System for applying loads has been installed. Strain gages and thermocouples have been installed and these are now being connected to the data recording system. Room temperature testing will commence early in December. Figure 25 shows the empennage test structure in the test fixture prior to installation of the Evener System.

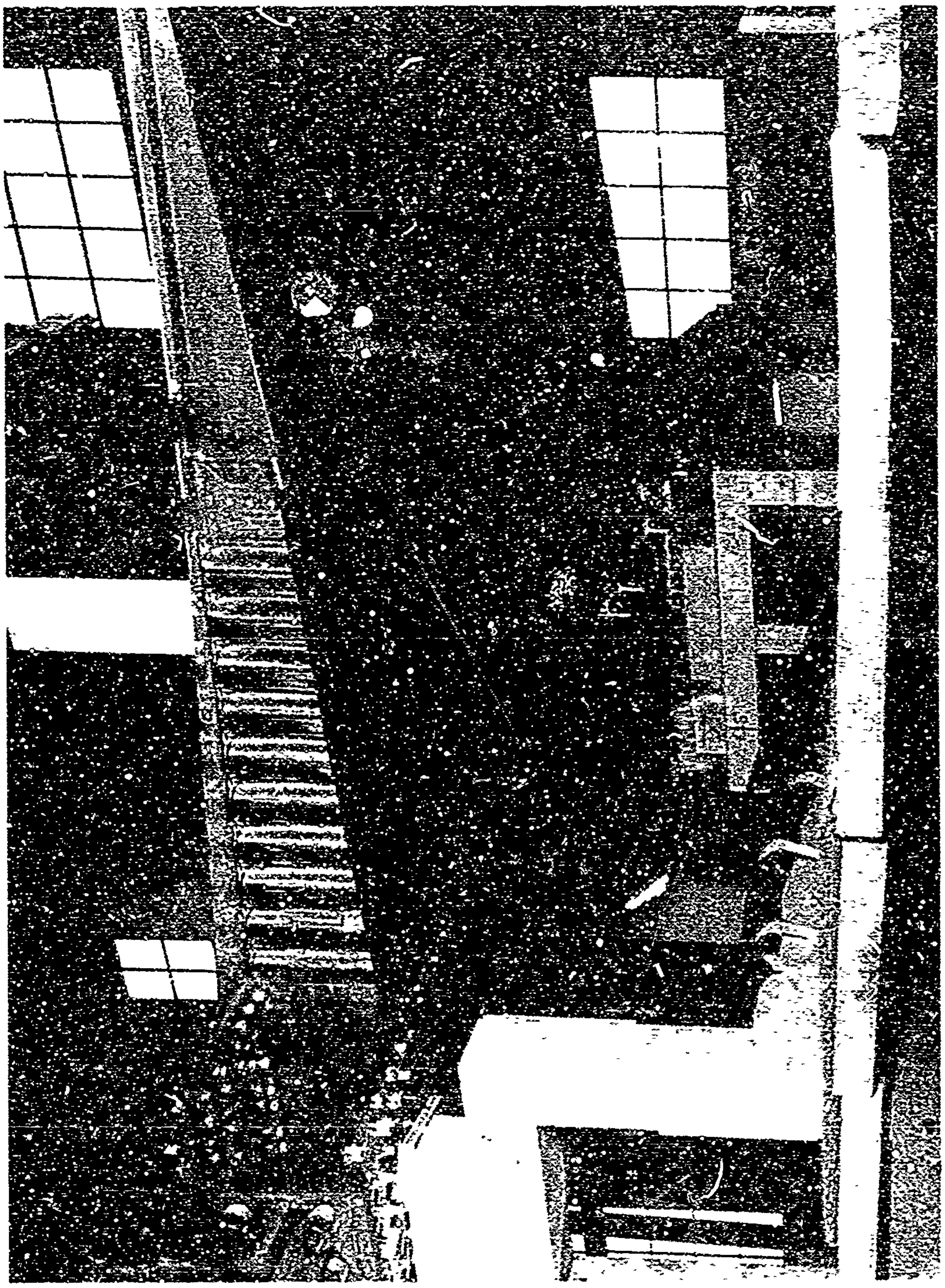


Figure 25. Stabilizer Test Structure

12 AIRFRAME SYSTEMS

1202 Environmental Control System (ECS)

(1) Compressor Development Program

As a result of the compressor failure (reported in the October Summary Letter Report), a higher strength ring gear has been fabricated and installed in a rebuilt compressor assembly. Instrumentation was added to measure the dynamic load conditions at the planetary gear carrier and torsional damper assembly. Other modifications include:

Improved lubrication of the sprag clutch

Addition of baffles to surround the fluid coupling adjacent to the ring gear to reduce oil splash and foaming

Reduction of oil flow to the planet and jack shaft gears

Modifications to the hydraulic coupling to reduce leakage and increase oil filling rate

Modification and calibration of controls to correct the overspeed trip point, and modification of the pre-whirl vanes to reduce actuation torque.

Compressor testing is scheduled to resume in early December

Accelerated endurance testing of the impeller wheel on a component test rig has satisfactorily completed 100 hours of operation.

(2) Wheel We[illegible]

Tests have [illegible] itiated to determine wheel well cooling requirements. The objective is to determine the optimum combination of cooling airflow rate, airflow distribution, and insulation.

The test assembly consists of a 367-80 landing gear (strut, truck, tires, and wheels) mounted in a simulated B-2707 main outboard wheel well. Electric heating blankets installed above and below the wheel well simulate the aerodynamic heating profile during a design mission including a two-hour cruise at 2.7 Mach.

Initial test results are being evaluated. The test is scheduled to be completed at the end of December.

(3) In accordance with the Detailed Work Plan, the "Air Boost Compressor Summary Report" was transmitted to the FAA per Boeing letter 6-2220-1142, dated November 9, 1966, to the attention of Mr. Larry Trenary.

1203 Hydraulic Systems

Delivery of the master control servo unit has been delayed from December 5th to December 23rd because the high temperature aluminum alloy actuator housing was improperly heat treated, requiring procurement of new forged blocks.

Several vendors have responded to the metallic-type bellows reservoir problem statement. As a result of their responses, a new problem statement has been released which will use engine bleed pressurization. Use of bleed air pressurization will reduce the differential pressure on the bellows permitting the use of welded bellows and, consequently, lighter weight construction.

The WSX 6885 pump loop test was shut down at 390 hours because of excessive system fitting leakage. Seal extrusion and excessive nibbling was noted at the system teardown inspection. Since the system was assembled with a new lot of O-rings, a seal material evaluation program has been initiated in addition to coordination with Humble Oil Company. Humble Oil reported on the problem in a meeting at The Boeing Company on November 29th. In the meantime, new seals were installed in the system and the system reactivated. Test time now stands at 600 hours.

All reconnectable fittings, except Cono-seals, passed the first series of repeated assembly tests. The second phase consisting of 50,000 impulse cycles to 4500 psi has not been completed due to seam weld failure in the 6Al-4V tubing at approximately 25,000 cycles on all specimens. Metallurgical examination of the welds is under way. In addition, procurement of seamless 3Al-2.5V tubing and 6Al-4V seamless tubing from Kilsby Tubing Company has been initiated. They will supply 3Al-2.5V tubing in 1-1/4 diameter size 5 weeks after procurement of the tube hollows. No commitment was established for 6Al-4V tubing because of fabrication problems in sizes under 1 inch.

A design review and program status review of the SST pump program was held at ABEX on October 28th. A complete report has been submitted to the FAA.

1204 Flight Control System

The elevon actuation arrangement was revised to eliminate the actuator fairing pod to reduce drag. A new actuator was designed which will remain within the horizontal stabilizer surface except at extreme travel positions.

III Description of Technical Progress (continued)

1204 Flight Control System (continued)

The wing sweep actuation system was revised to allow the wing to be positioned at 20° leading edge sweep during landing. The wing sweep control system was revised to allow the wing sweep actuator to position the movable wing to less than 30° sweep when the trailing edge flaps were deflected.

The longitudinal master servo, the longitudinal and lateral SAS power units, and longitudinal and lateral mechanical programmers were relocated in the fuselage from behind the stabilizer rear spar to forward of the stabilizer front spar. The change was made because of decreased space available aft when the fuselage was revised to the twin aisle seating concept forward and the aft fuselage section was decreased.

Methods of achieving direct lift control to improve the flight path control capability during landing were studied and a system using the wing spoilers was selected. The system utilizes a triple channel electro-hydraulic servo in each wing to introduce the direct lift control signal into the spoilers. The direct lift control function is automatically engaged when the wings are swept forward to 20°. The spoilers are raised to 3° above the faired position and pitch control inputs command increased or decreased spoiler positions in parallel with the elevator surfaces.

The above items along with updated diagrams are included in Boeing document V1-B2707-5 "Model B-2707-100 Description".

A detailed test plan, Report D6A10441-1, covering both the developmental servo simulator and the flight control servo simulator, has been prepared and released. This document provides descriptions of the testing fixtures and the proposed facility, as well as giving a step-by-step discussion of the planned testing program.

Approximately 50 percent of the drawings for the fabrication of the DSS have been released. The balance are in checking. About 10 percent of the installation drawings have been completed and await checking and final approval. Nearly all purchased parts and material have been received or have been placed on order.

Testing has been completed on the variable rate spring which will be used to simulate the compliance of the airframe structure. The design has been verified and drawings released for manufacture of parts for the servo simulator.

The 10-61061 servo actuator being built by Bertea is scheduled for shipment in the middle of December. Prior to final installation in

1204 Flight Control System (continued)

the developmental servo simulator, the master servo will be tested separately for control characteristics. The main servo will be used for a recheck of the stability augmentation system servos.

1205 Electrical Systems

12051 ELECTRICAL POWER SYSTEMS

Document D6A10451-1, Electrical Power Subsystem Test Plan and Requirements, was prepared and released. This document supplements the previously published test plans and provides a summary of all electrical components and system tests required to develop, qualify, and integrate the electrical power system defined by the Electrical Subsystem Specification, D6A10119-1.

Detailed requirements for the control of the VSCF system have been formulated and are being included in the VSCF Specification, D10-61114. The revised specification will also contain an expanded test requirements section, reflecting the detailed design work accomplished in the last r ing period.

Electrical Power System Test Rig

A breadboard test rig built to test the automatic switching logic for the electric power system split-bus distribution arrangement has been completed. A motion picture film was prepared to illustrate the automatic operation of the electric system during normal start-up, operation, and shut down, as well as automatic switching for fault protection and isolation. Document D6A10439-1, "B-2707 Electric System Switching and Logic Test Rig Demonstration", records the narrative description which accompanies the motion picture film. Document D6A10439-2, "B-2707 Electric System Switching and Logic Test Rig Demonstration - Supplement", records the schematic and wiring diagrams for the switching logic test rig.

Variable Speed - Constant Frequency (VSCF) Power Generation System Program

The developmental contracts which were awarded to General Electric Company and Lear Siegler, Inc. to study and develop VSCF system prototype hardware items is proceeding with final reports to be submitted by January 1, 1967. The contract with GE is for study and development testing only; the contract with LSI also includes the completion of a prototype generator.

III Description of Technical Progress (continued)

12051 Electrical. Power Systems (continued)

Progress over the report period includes the following:

A. Lear-Siegler, Incorporated

1. Generator layout complete

   a. Heat transfer studies complete

   b. Stress calculations and natural frequency calculation on rotor complete

   c. Lamination drawing released

   d. Casting drawing complete

   e. Shaft disconnect layout complete

2. Generator Component Tests

   a. Design and fabrication of rotor for spin test complete.

   b. Diode spin test complete - The stud mounted GE and Motorola type 1N1190 series unit successfully withstood inertia forces equivalent to generator speeds to 27,000 rpm (18,000 g's) at ambient temperatures ranging from 100° to 375°F. Electrical characteristics in each case were essentially independent of speed (inertia force) over the complete range of test temperatures.

   c. Rotor Spin Test - Design and fabrication of test rig complete. Initial test runs on the rig resulted in excessive leakage through the dynamic seals. This problem is currently under investigation.

   d. Corona Tests - Tests on terminal block and connector assembly are in process. Preliminary evaluation of test results to date on the terminal block assembly indicates increase in some spacing and clearances desirable to prevent breakdown during high altitude operation.

3. Power Converter

   a. Design of power converter components (isolation reactances, frequency converter modules, and output transformer) is complete and components are under fabrication.

III Description of Technical Progress (continued)

12051 Electrical Power Systems (continued)

b. Design of system controls is 90 percent complete.

c. Design of printed circuit boards for control circuits is over 50 percent complete.

d. All control circuits have been breadboarded and tested to verify operation.

4. Development Generator
Buildup of the test generator is 90 percent complete and is on hold-up until design changes have been determined for resolution of the rotor lamination separation problem and the seal leakage problem.

The generator being built by Lear Siegler for Boeing will be retained by Lear Siegler until March 31, 1967 to support additional tests to be accomplished in the first quarter of 1967.

A. General Electric Company

1. Bearing and Seal Study

a. Analytical studies on the bearings and seals complete.

b. Tests were completed on evaluation of bearing and seal system, bearing seals, and the transfer seal, on October 28. Test results were as predicted.

2. Rotating Rectifier Study
Five types of rectifiers were spin tested and hot and cold tested. Several types of the test rectifiers appear as likely candidates for the SST VSCF generator. Tests were completed October 19, 1966.

3. Torque Transfer Study

a. Tests were completed on November 25, 1966.

b. The final report will be completed in early December.

4. Rotor Dynamics Study

a. Analysis was based on recommendations made to resolve the critical speed problem. This study was completed October 28, 1966.

b. The final report will be completed in early December.

III Description of Technical Progress (continued)

12051 Electrical Power Systems (continued)

5. Final Generator Design

   a. Final generator design is scheduled to be completed by the end of december.

   b. Design Summary

      1. Catalog rectifiers appear to be suitable for the the end of December. Silver-lead solder will be used to solder leads to rectifiers.

      2. Final bearing design has been selected. Bearing size depends upon critical speed analysis.

      3. Bearing Scavenge
         The scavenge system appears adequate for the design oil flow.

      4. Seals
         Study seal configuration (0.003 radial clearance, screw seal) appears to be suitable over the speed range of the generator.

      5. The generator disconnect has operated within limits over the design speed range.

      6. Rotor Construction
         Testing of the generator rotor indicated no yielding of the top sticks or end rings at speeds up to 20,000 rpm.

12052 ELECTROMAGNETIC INTERFERENCE CONTROL

The results of laboratory testing to refine data on wire coupling and the shielding effectiveness of titanium structure has been summarized in test report T6A10324-1, "EMI (Electromagnetic Interference) in Titanium Airplanes - Laboratory Evaluation Tests to Develop Design Guidelines".

Document D6A10460-1, "SST Electromagnetic Interference (EMI) Control Plan", is being prepared and will be released in early January. This document describes the various methods, design controls, and tests planned for achieving electromagnetic compatibility in the prototype SST and associated ground support equipment.

III Description of Technical Progress (continued)

12053 ANTI-COLLISION LIGHTS

An extensive study of anticollision light effectiveness, particularly during supersonic cruise conditions, has been completed during this period and is being released as Boeing Document D6A10471-1.

The analysis indicates that effective anticollision lighting can be achieved during supersonic cruise by using white anticollision lights of 1000 candle power.

FAR changes, based upon these conclusions, have been discussed with the FAA.

12054 WIRING AND TERMINATIONS

On November 15, 1966, Boeing sponsored an "Electrical Wire and Connector Industry Presentation". A total of 129 representatives from 34 companies were in attendance. The purpose of the meeting was to show Industry the potential SST wire and connector market and to encourage them to participate in developmental effort on SST problem areas. Specific follow-up action desired by Industry was outlined.

The supplier reaction to the presentation was excellent and a number of possible hardware alternatives were mentioned during informal discussions. Several of the companies indicated they would submit proposals by January 1, 1967, as requested.

1206 Accessory Drive Subsystem

(1) The following items were accomplished in accordance with the Detailed Work Plan.

(a) Accessory drive operating demonstrations were conducted at the suppliers.

(b) The Sundstrand accessory drive summary report was submitted to the FAA.

(c) The Hamilton Standard accessory drive summary report submittal date was moved from November 1 to December 15.

(2) Sundstrand ADS Development Program
The demonstration test was successfully conducted from September 30 to October 3, 1966. Problems encountered during the demonstration and endurance test have been resolved and testing resumed. The vibration test was started on November 24th. At the completion of the vibration test, the remainder of the endurance test and follow-on testing will be conducted. A design review was held at the Sundstrand facility on November 3, 1966.

(3) Hamilton Standard Development Program

The one-day demonstration test was conducted on November 21, 1966. Supplemental oil was supplied to the spiral bevel gear area during this test to maintain satisfactory bearing temperatures. Failure of the sprag clutch and disconnect screw thread occurred during the test.

Testing is scheduled to resume in early December for evaluation of modifications to reduce the spiral bevel gear bearing temperature.

A design review was held at Hamilton Standard's facility on November 4, 1966.

1207 Automatic Flight Controls

During the reporting period, a mechanization for a direct lift control function using spoilers was developed. A description was incorporated in the December 31, 1966 revision of the subsystem specification.

In addition, a series of meetings have been held with four potential suppliers of Flight Control Electronics. At these meetings, the potential suppliers indicated their willingness to participate in studies to define possible flight control electronics mechanizations best suited to the Boeing application. These efforts will culminate in a final data submission to Boeing in approximately three and one-half months.

1208 Flight Deck Installations and Systems

During October and November the flight deck design was reviewed with the Air Line Pilots' Association, the Allied Pilots' Association, and various non-U.S. and U.S. Air Line flight crew representatives. Their constructive criticisms have been recorded and are being considered in the continuous process of design refinement.

(1) Design

The Flight Deck Subsystem Specification has been updated to reflect the effects of the B-2707-100 changes and to replace several incorrect figures which were inadvertently used in the original issue.

1208 Flight Deck Installations and Systems (continued)

Staff studies are in process to define the display and interface requirements for time sharing the weather radar display with television viewing and vertical navigation (profile) data.

The flight deck instrumentation requirements have been defined for the purpose of establishing the detailed amplifier requirements for the flight deck system integrated simulator.

(2) Procurement

New development equipment items for the flight deck are (1) crew seats, (2) pitot-static system components, (3) windshield rain removal system, and (4) vertical scale instruments for monitoring systems, temperatures, and pressures. The specifications are nearly complete for all but the vertical scale instruments, and these will be completed during December.

1210 Navigation

One engineering test model nose radome being manufactured by The Brunswick Corporation was subjected to artificial lightning tests prior to delivery to Boeing. Several areas of localized damage occurred. This damage is not expected to compromise the structural integrity of the radome. The second test model radome successfully withstood its structure and environmental testing and has been received in Seattle.

1213 Passenger and Cargo Provisions

12130 Passenger and Cargo Provisions, General

Studies continued on deck plans and cargo provisions for the twin-aisle B-2707-100 configuration. Significant results were reported in V1-B2707-5, Model B-2707-100 Description.

Document D6A10468-1, "Fire Safety Development and Demonstration Program - 2707 Interiors Design," was prepared during this reporting period for release in early December.

III Description of Technical Progress (continued)

13 PROPULSION SYSTEMS

1300 Propulsion Systems – General

The GE propulsion pod location on the B-2707-100 stabilizer is 60 inches aft of the B-2707 location. A refined pod shape (P-ENG-622) has been developed for the B-2707-100 airplane configuration. The new shape and location results in a considerable improvement in the fairing between the stabilizer upper surface and the nozzle. The depth of the gully in the stabilizer upper surface is reduced by approximately 14 inches (from 16.5 to 2.5 inches at the pod vertical ℄). Location of the engine rotating machinery relative to airplane structure and systems is significantly improved.

1301 Performance (Installed)

Mach Number Study

Engine performance studies were made for a range of cruise Mach numbers of 1.7 to 3.2. These studies were based upon two augmented turbojet engine cycles used in current supersonic transport design; a medium pressure ratio single spool machine and a high pressure ratio two-spool machine. Of the two cycles, inlet/engine airflow matching characteristics of the two-spool cycle was found to be better suited to the low Mach number range. The single spool machine was found to be more suitable for the Mach range 2.7-3.2, but was less adaptable at lower Mach numbers, due to difficulties in engine/inlet airflow matching.

Engine performance decks were generated for six possible Mach number/cycle combinations for use in airplane performance studies which are presented in Boeing Document D6A10483-1 "Effect of Sonic Boom Requirements on Airplane Sizing and Economics."

GE4/J5P (October 7)

Performance data and IBM decks were received from GE for an uprated version of the GE4/J5P for Standard, Standard +10°C and Standard +15°C days. This engine is the initial service production version which has an airflow of 633 lb/sec and a maximum thrust of 67,000 lb at sea level static conditions. The transonic thrust has increased about 6 percent due to increased turbine inlet temperature, airflow, and increased maximum augmentation temperature during climb and acceleration. In addition to the above performance decks, a prototype engine deck was compiled in accordance with instructions provided by GE.

The B-2707-100 performance characteristics with the 633 lb/sec GE4/J5P engine were presented in Boeing Document V1-B2707-5, dated Nov. 14, 1966.

III Description of Technical Progress (continued)

1302 Air Induction System

(1) Inlet Test and Analysis

(a) Low Speed Inlet Performance

A series of 1/10 scale inlet low speed performance tests were run during late November 1966. The test model simulated the B-2707-100 airplane configuration and the Phase III proposal inlet configuration. Model and test configuration photos are shown in Figs. 26 and 27. Substantial inlet performance improvements were obtained relative to the airplane and inlet configurations tested earlier. The three major reasons for improvements were:

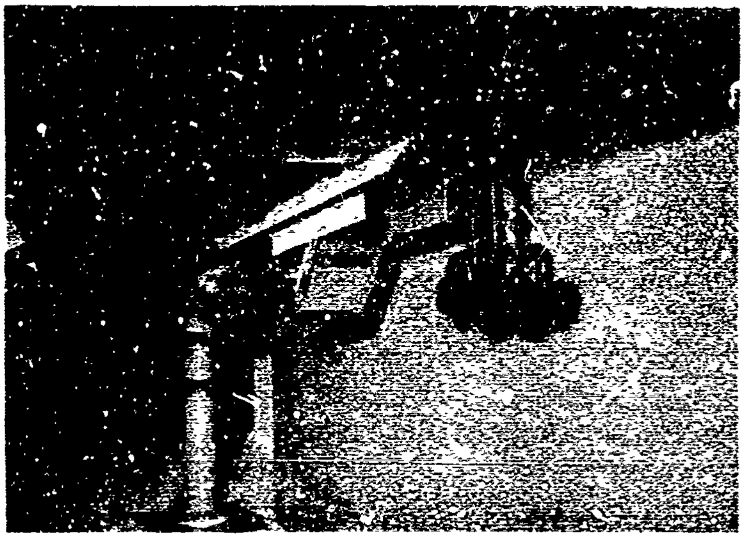
- Improvement in Takeoff Door Design.
  Figure 29 shows the suck-in type takeoff doors of the Phase III proposal inlet and the sliding lip type doors of the older configuration used in previous tests. The improved design moves the minimum flow area inside the inlet and allows the major flow-turning to take place while the flow is accelerating. This provides more effective takeoff area which, in turn, reduces flow and velocities at the inlet cowl lip.
- Aft Movement of the Inlet Relative to the Flaps.
  The B-2707-100 configuration provides better turning of the flow before it enters the inlet. Figure 28 shows a sketch of the relative inlet locations for the B-2707-100 and the earlier B-2707 (GE).
- Improved Flow Channel through Wing Flap Cutout.
  The lower aft corner of the inboard wing cutout was rounded as shown in Fig. 28, contrasted to the sharp corner used in the B-2707 configuration.

The model installation provided test capabilities from 0 to 10° angles of attack of the wing (and inlet). The simulation of the B-2707-100 configuration included the 4-post main landing gear, the correct inlet spanwise and axial location relative to the flap, door systems for closure of the wing flap cutout (when the flaps are retracted) and the outboard wing flap system. The outboard flap was removed for the majority of testing to minimize tunnel blockage. However, results of several tests which were not blockage critical showed no effect of the outboard flaps on the inboard inlet performance (test comparisons were run at 80 and 130 knots at an airplane angle of attack of 0°).

The inlet had vortex generators and inlet centerbody struts installed with 11 takeoff doors open (12th door under pod strut closed). The compressor face instrumentation consisted of 64 steady state total pressure probes (8 rakes with 8 probes per rake) and 2 dynamic total pressure probes good for 1000 cps data.

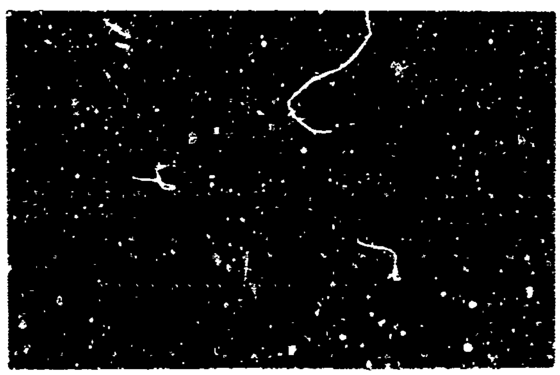
Test Results

The improvement of inlet takeoff performance can be seen in Fig. 29 where earlier B-2707 data is compared with the present B-2707-100

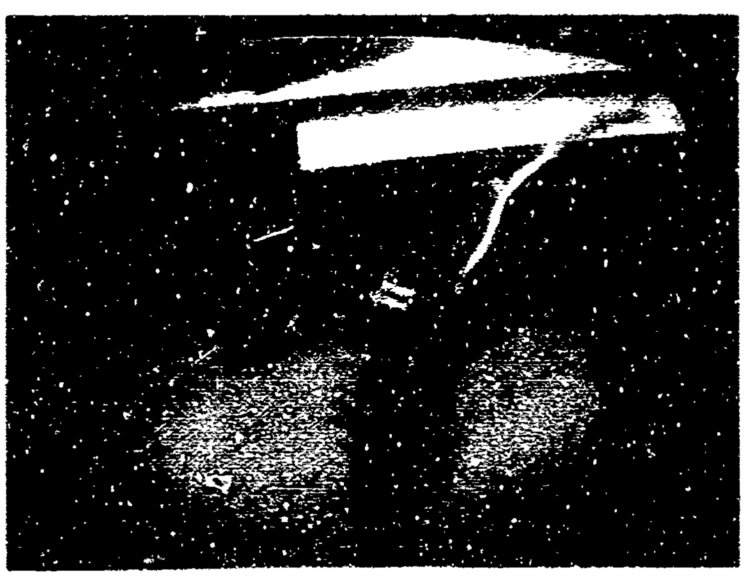


RELATIONSHIPS
OF
INLET-FLAPS
DOORS-GEARS

(OUTBOARD FLAPS
REMOVED)



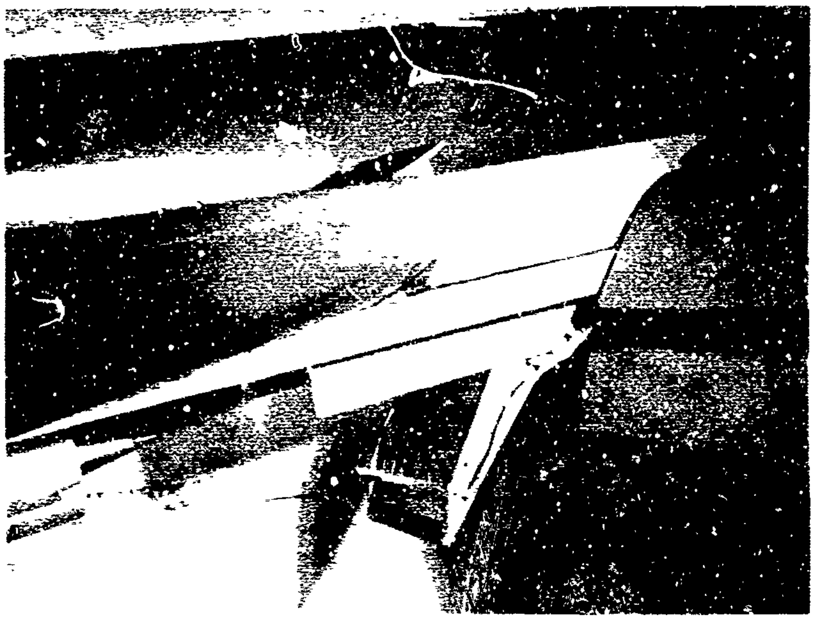
INLET-FLAP
ALIGNMENT



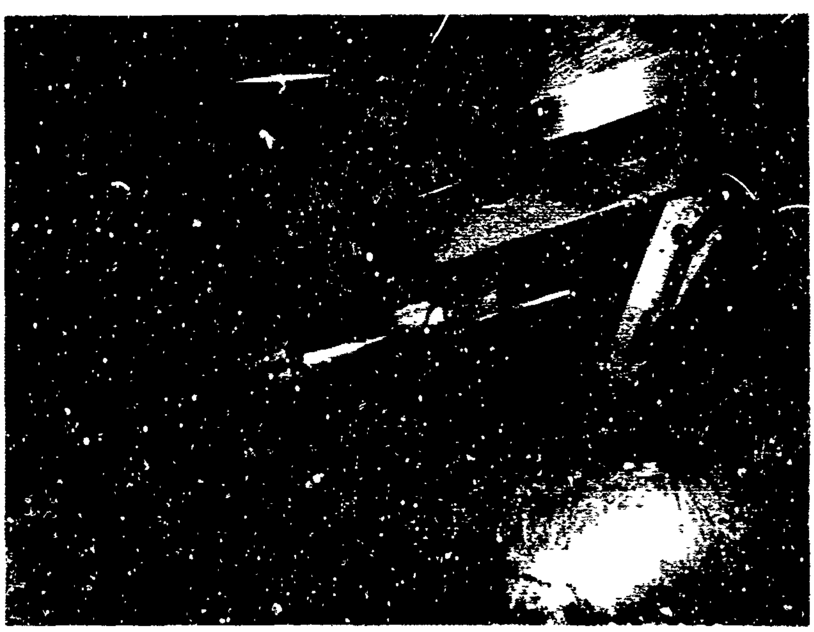
FLAPS WITH
TUFTS TO SHOW
FLOW ATTACHMENT

$\alpha = 5^\circ$
FLAPS AT 40°
160 KNOTS

Figure 26. Model Test Configurations

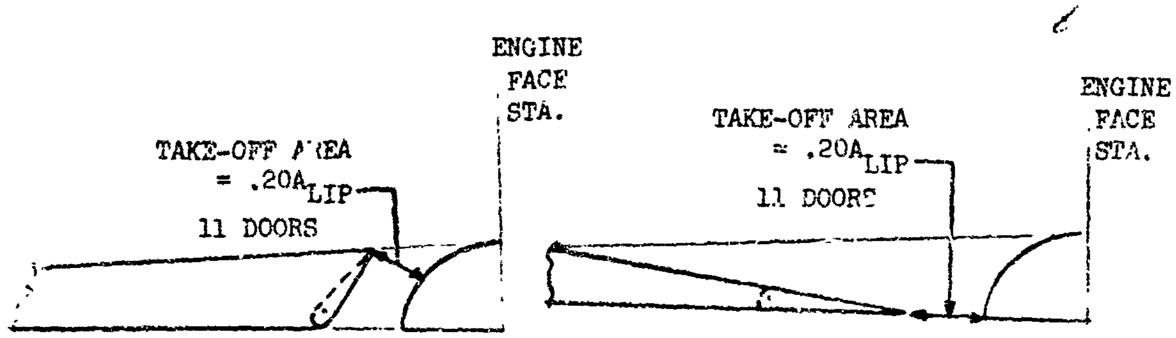


INLET AND
INBOARD-OUTBOARD
FLAP SYSTEM



INLET AND
FLAP DOORS
$\alpha = 10^{\circ}$

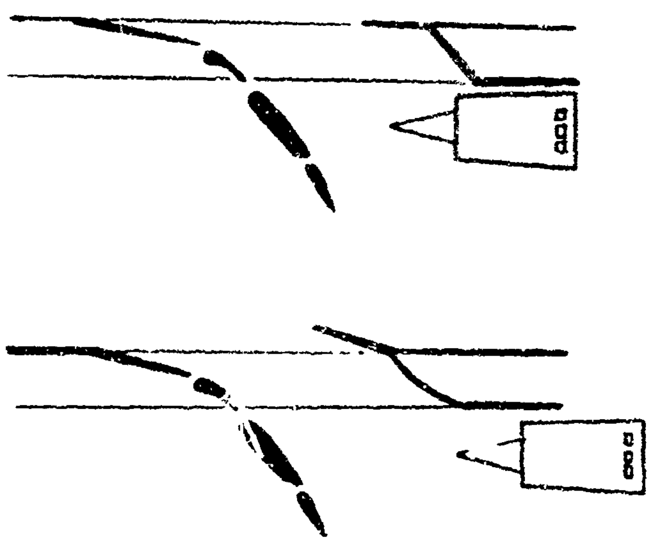
Figure 27. Model Test Configurations



SIMULATION OF SUCK-IN DOORS FOR B2707-100 LOW SPEED INLET TEST

TAKE-OFF DOORS SIMULATED FOR DATA SHOWN IN B2707 PROPOSAL.

DETAILS OF INLET TAKE-OFF DOORS



B2707 CONFIGURATION

B2707-100 CONFIGURATION

Figure 28. Details of Inlet-Flap Relationships

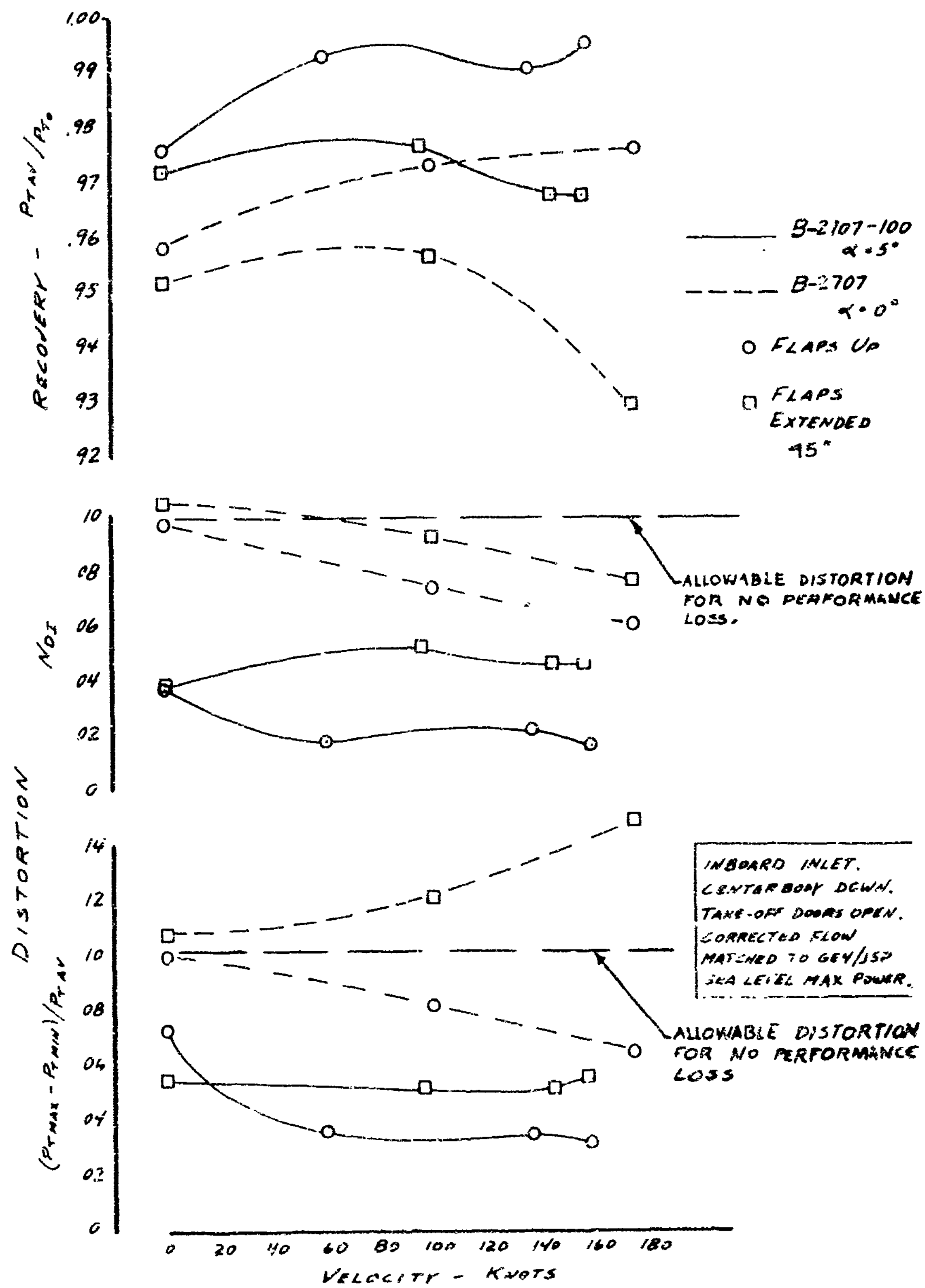


Figure 29. Comparison of B-2707-100 and B-2707 Low Speed Inlet Performance

data for the flaps full down (45°) and full up at various airplane speeds. Figures 30 through 33 show B-2707-100 inlet performance data for variations in angle of attack and flap position, and the effect of inlet choked mode operation.

The absolute turbulence levels recorded are shown in Fig. 34 for angles of attack of 0, 5 and 10 degrees. The overall turbulence levels decrease with increasing velocity. The turbulence at zero velocity indicates the turbulence is mainly generated within the inlet. Only two dynamic probes were installed at the compressor face. The data have not yet been frequency analyzed and fully evaluated. Data shown in Fig. 34 was obtained from electronic RMS meters and plotted as turbulence equal to 6 $\Delta P_{T_{RMS}}/PT_{AV}$.

Inlet generated turbulence will be studied further to define parameters affecting turbulence generation. A J85 engine will be run with a similar inlet (1/3 scale) in the last half of December 1966 at speeds from 0 to 200 knots and with dynamic instrumentation as in the present 1/10 scale low speed test. Data from this test will show how a close coupled engine affects the inlet turbulence levels and how the engine performs with these turbulence levels imposed.

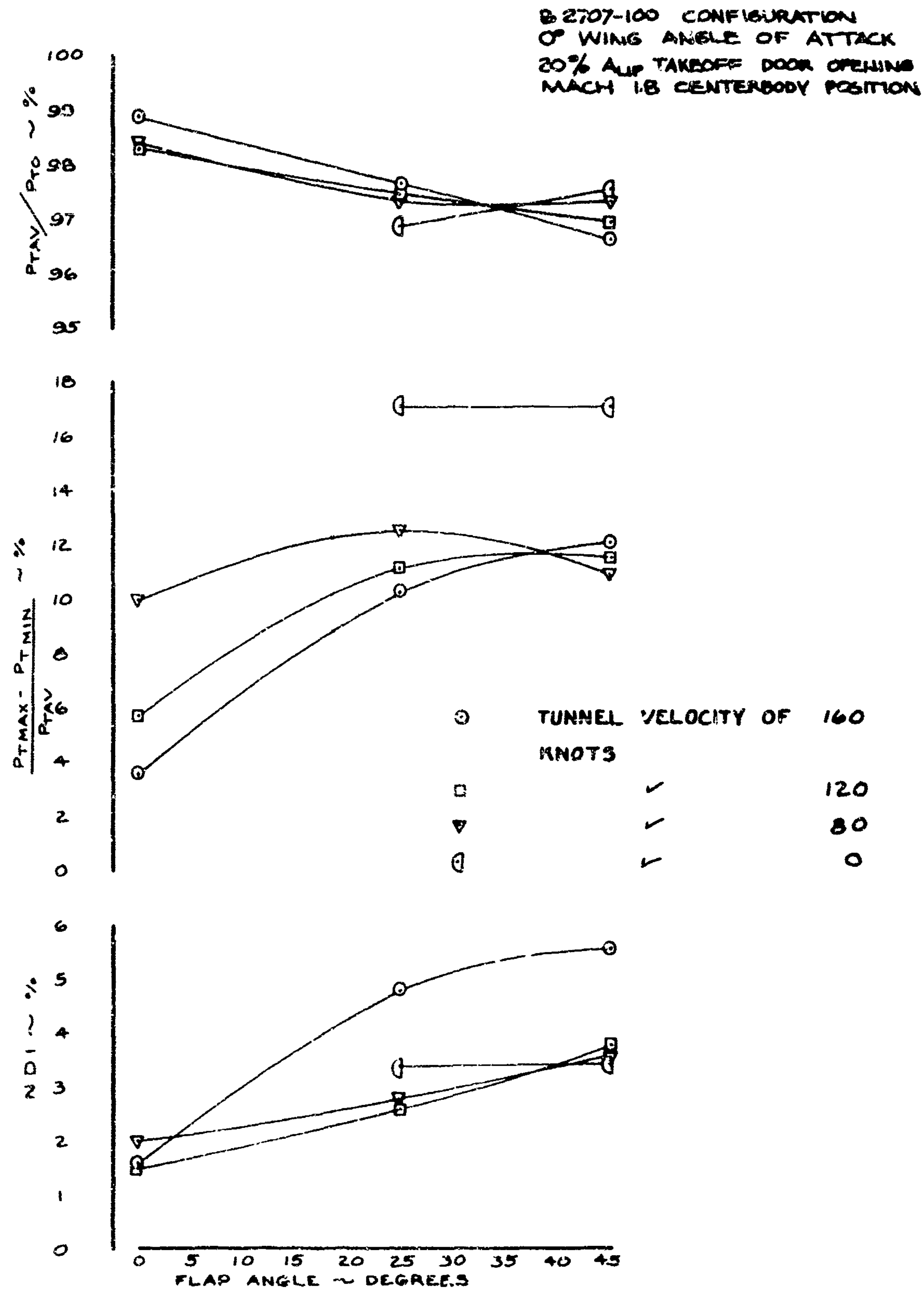
Velocities over the inboard flap segments were measured at various angles of attack and flap settings, both with and without inlet suction. The data shown in Fig. 35 indicates a small increase in velocity and no separation when the inlet is operating behind the flaps.

(b) 1/3 Scale Inlet - J85 Low Speed Testing

Installation of the 1/3 scale inlet-J85 engine is scheduled to begin in early December, in the Boeing low speed induction tunnel. Testing will start around the middle of December and continue until the end of the month.

(c) 1/5 Scale Inlet - Performance and Control Testing, Mach 1.8 to 2.6

The 1/5 scale inlet is being built up with bypass door system as in the October 28 proposal, for internal performance and control testing. The eleven sets of 3 external louvers are simulated with eleven single flaps. Testing will begin around mid-December 1966.



30. *Inlet Performance at Engine-Inlet Match Airflow and 0° Angle of Attack*

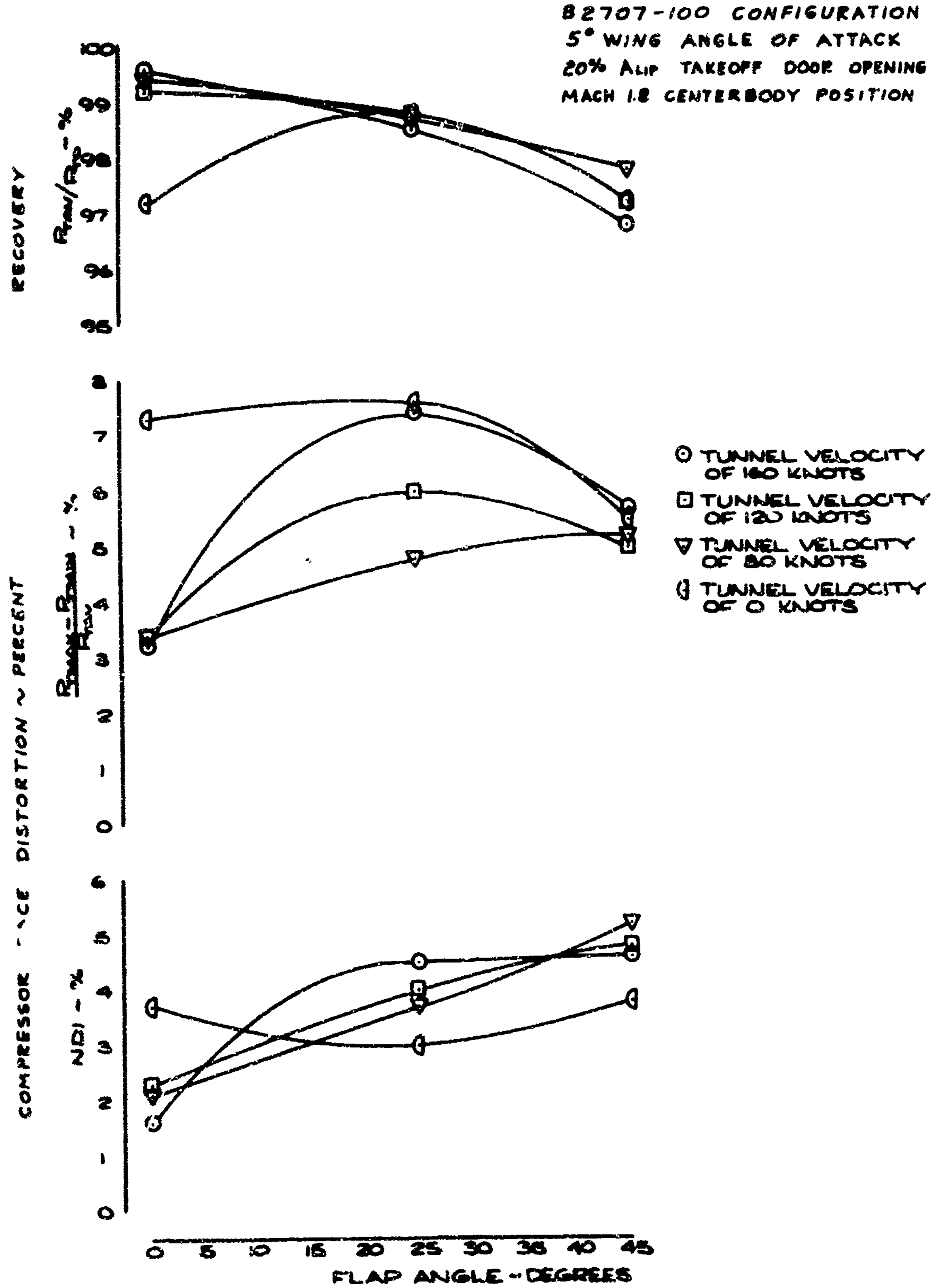


Figure 31. Inlet Performance at Engine-Inlet Match Airflow and 5° Angle of Attack

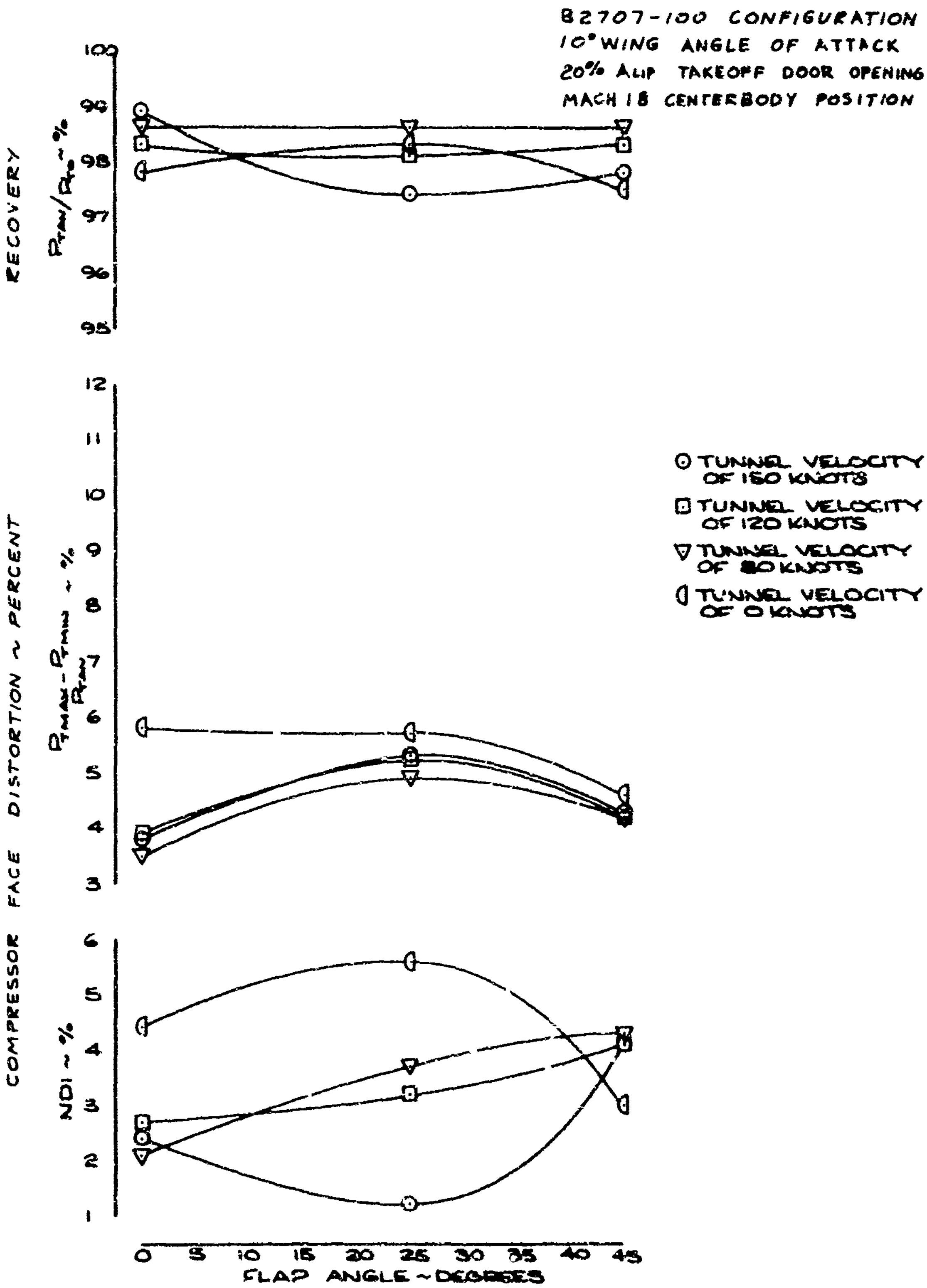


Figure 32. Inlet Performance at Engine-Inlet Match Airflow and 10° Angle of Attack

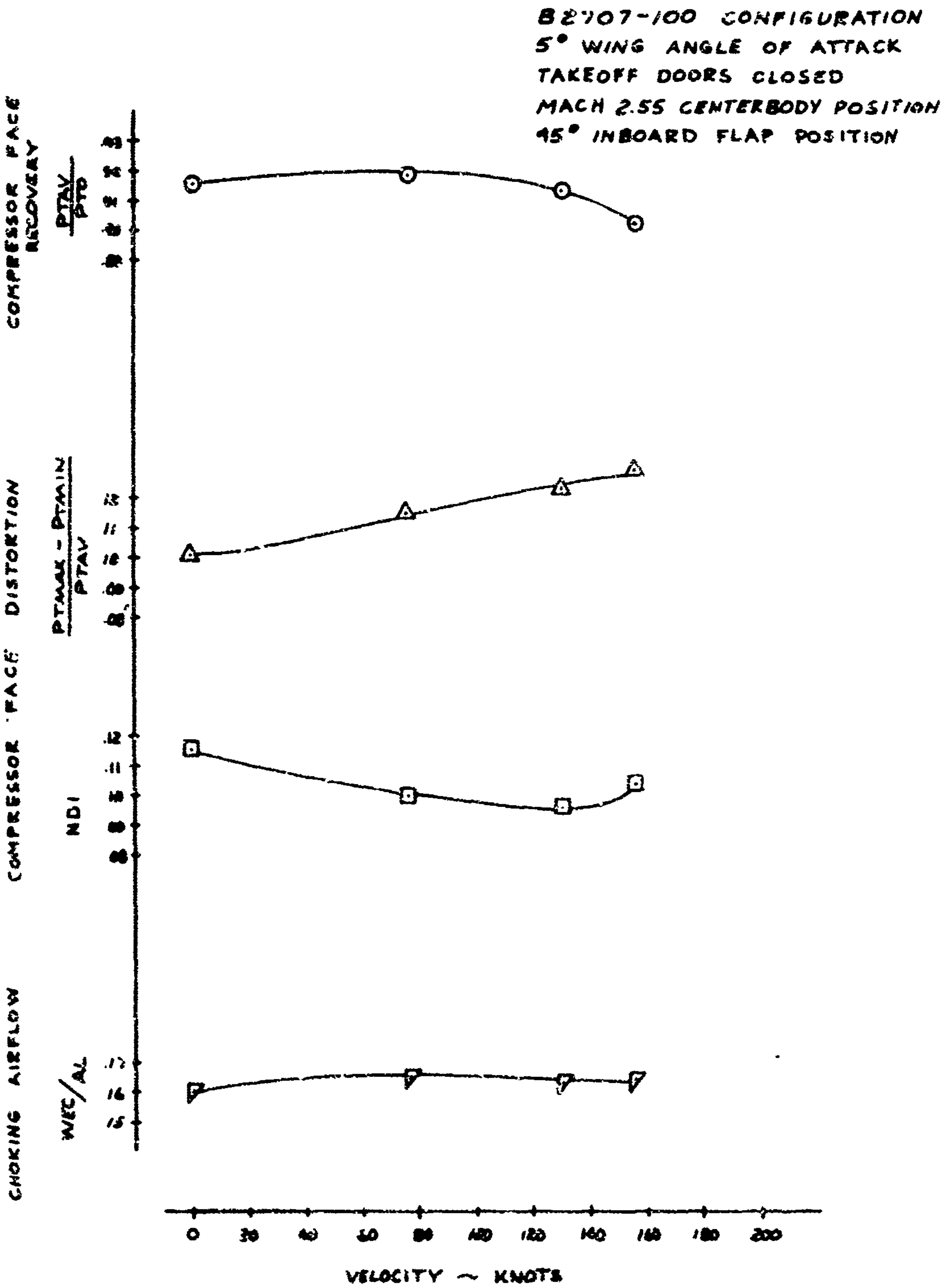


Figure 33. Choke Flow Performance Behind Extended Flap System

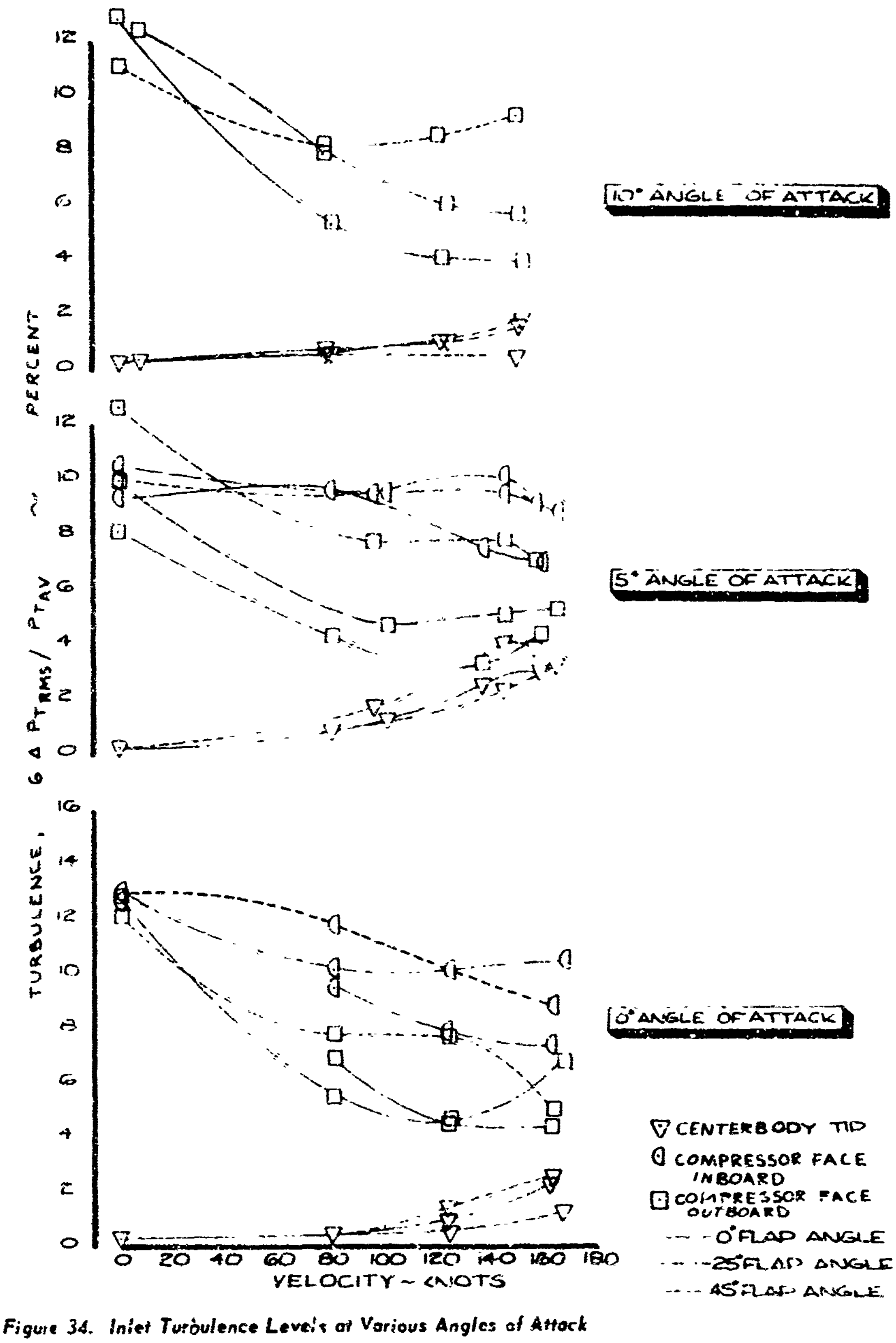


Figure 34. Inlet Turbulence Levels at Various Angles of Attack

D6-19110-P

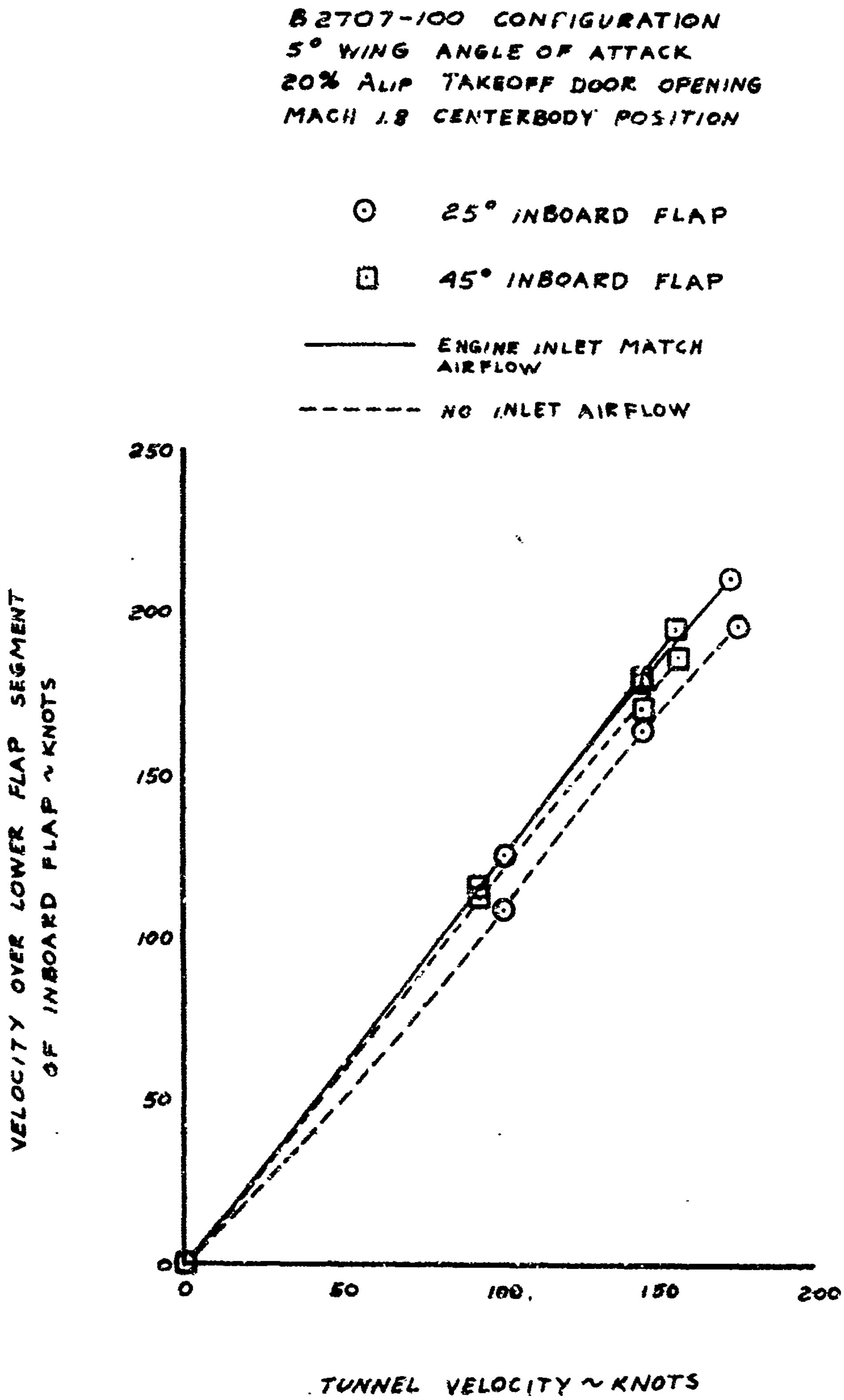


Figure 35. Effect of Inlet Suction on Velocity Over Inboard Flap

1302 Air Induction System (continued)

(4) Test Schedule

Figure 36 shows the schedule of various propulsion tests through December 1966.

1303 Air Induction Control

(1) Simulation Studies

The inlet and inlet control mathematical models have been updated and modified to include the effects of the vortex valve and a more rigorous representation of the hydraulic system; i.e., the fluid friction based on the latest hydraulic circuit design, energy loss due to inertial forces, valve and quiescent leakages, etc. Necessary loops and logics were also added to simulate inlet restarts. Preliminary simulation runs are being made with the mathematical models.

The construction of mathematical models of the 1/5 scale variable geometry inlet model to simulate the wind tunnel test results is nearly complete. The mathematical model is now in its checkout stage.

(2) Test Results

The local Mach number ahead of the inlet is measured by a centerbody tip total pressure and four cone surface static pressures. The inlet Mach number is used for computing the inlet critical recovery which is used for displaying the inlet operating condition at the flight deck. A summary of wind tunnel test results of the total and static pressures measured with 0.06 scale and 1/5 scale inlets is presented in Fig. 37. The data show that the maximum deviations of the measured inlet Mach number from the tunnel nominal Mach number was 0.05 Mach. Additional tests, with direct ratio measurement (rather than individual pressure measurement) will be conducted to determine the degree of improvement possible.

The wind tunnel test results of the centerbody control loop with the 1/5 scale variable geometry inlet were analyzed and the closed loop frequency responses were plotted in Bode plot form. The results are presented in Figs. 38 through 41. The block diagram of the centerbody loop together with the transfer functions used is shown in Fig. 42. All control system components except the servo valve, actuator, and associated hydraulic lines shown in the figure were simulated on an analog computer.

Two pressure ratio sensors were simulated; an electronic sensor with a time constant of 0.001 sec, and a hydromechanical sensor with a time constant of 0.015 sec. The input for the test runs was a sinusoidal change in inlet Mach number. The test data were curve-fitted for later use in a mathematical simulation and the resulting equations are presented in the figures. In general, it can be concluded that response speed is good up to 2 cps.

MODEL DESCRIPTION

Fluid Control for Stability Bleed Augmentation
Inlet Throat Vortex Valves
Facility: 18 x 18 inch VN Tunnel
1/5 Scale Inlet with Vortex Valves

Inlet Buzz Stability and Starting Characteristics
3 inch Inlet
Facility: 6 x 6 inch VN Tunnel

Inlet Performance and Control System Evaluation
1/5 Scale Model
Performance and Control Signals. Fixed
Geometry Performance
Variable Diameter Centerbody, Performance and
Control Signals. Variable Centerbody and
Bypass System
Control Signal Study and Analog Controller Operation
Control Dynamics Test
Facility: 18 x 18 inch VN Tunnel

Takeoff; Inlet Choked Model Testing and
Inlet-Airframe Low-Speed Compatibility Tests:

1/10 Scale - Takeoff, Noise, B2707 Config.

1/3 Scale Inlet - J85 Engine Test

Facility: 9 x 9 foot Low Speed Tunnel

Reverser Ingestion Test
1/20 Scale Airplane Model
Facility: 9 x 9 foot Low Speed Tunnel

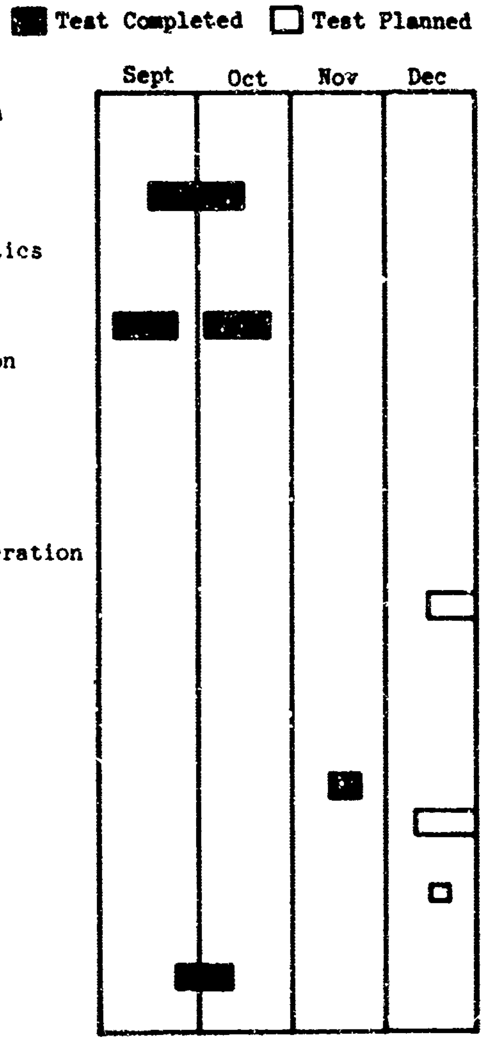


Figure 36. Propulsion Test Schedule

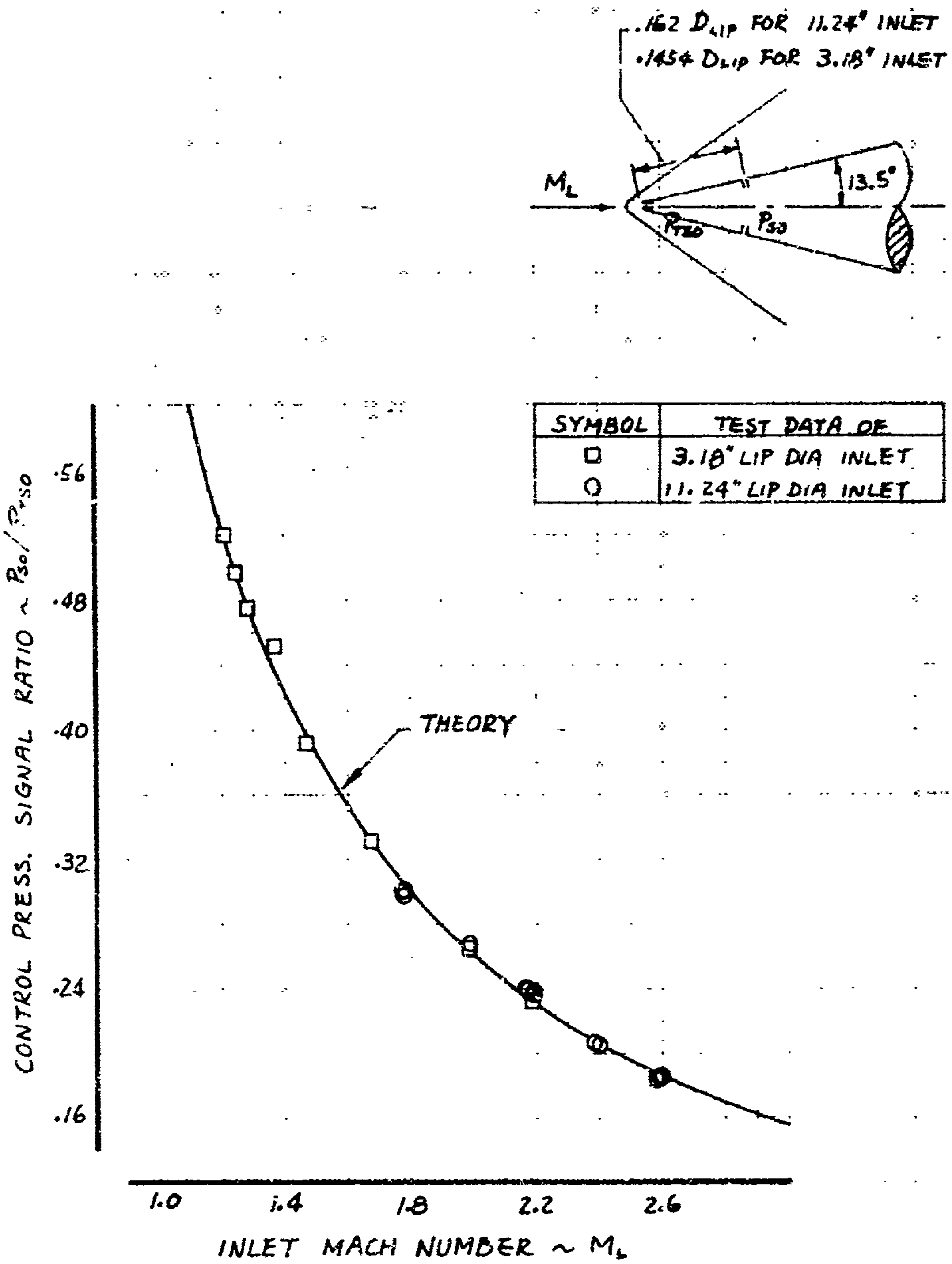


Figure 37. Inlet Mach Number Pressure Signal Characteristics

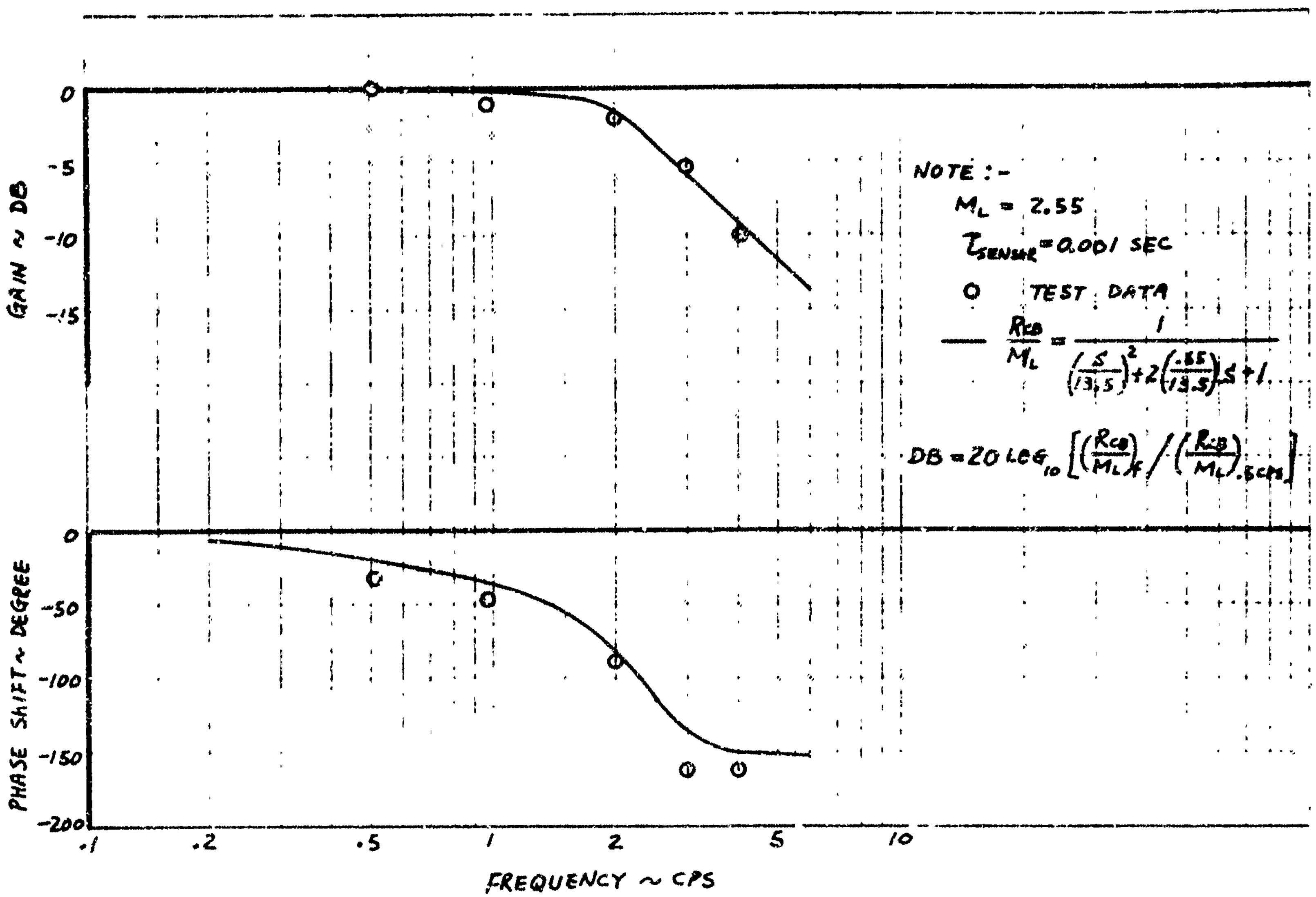


Figure 38. Centerbody Control Loop Response – Simulated Electronic Sensor

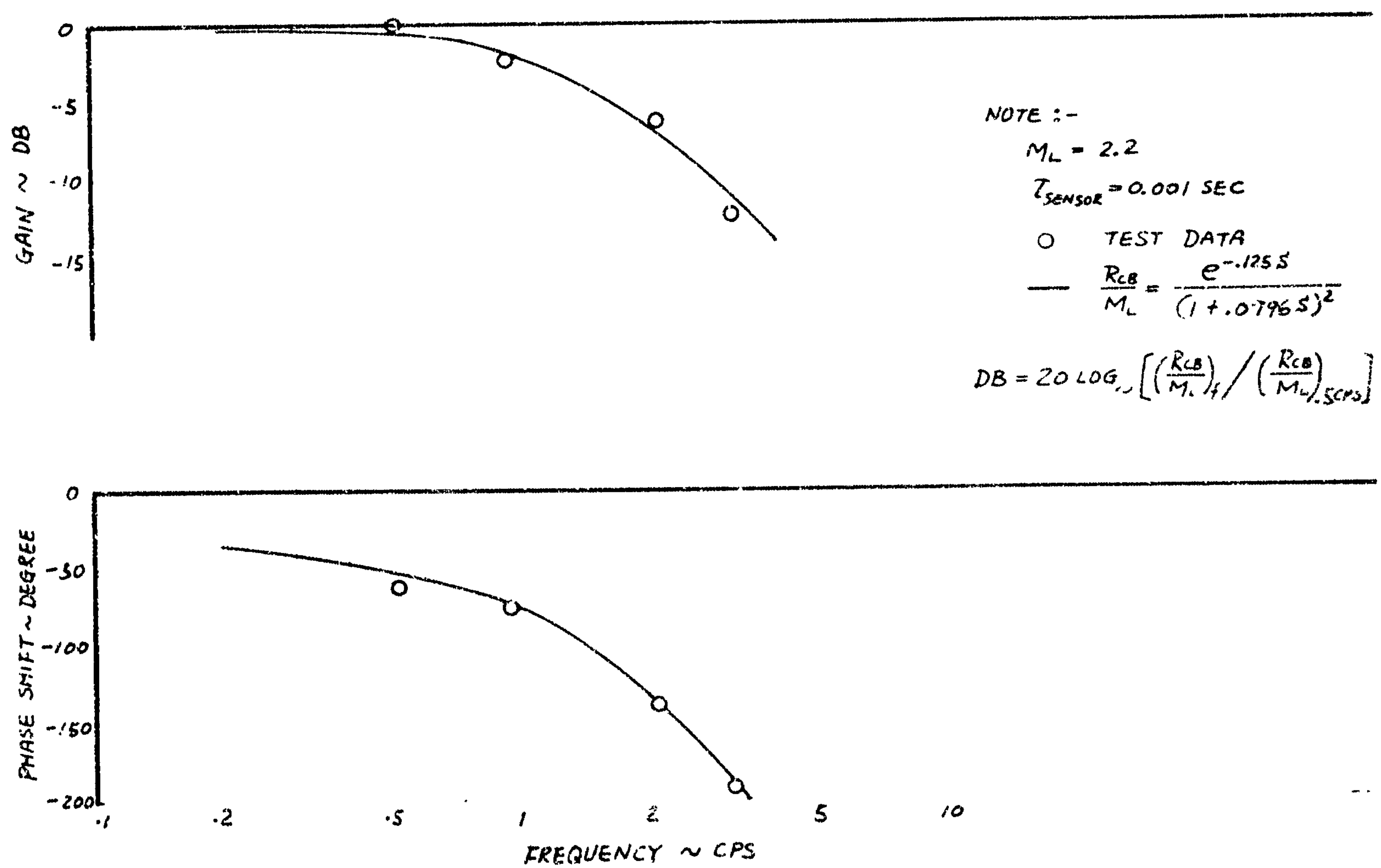


Figure 39. Centerbody Control Loop Response – Simulated Electronic Sensor

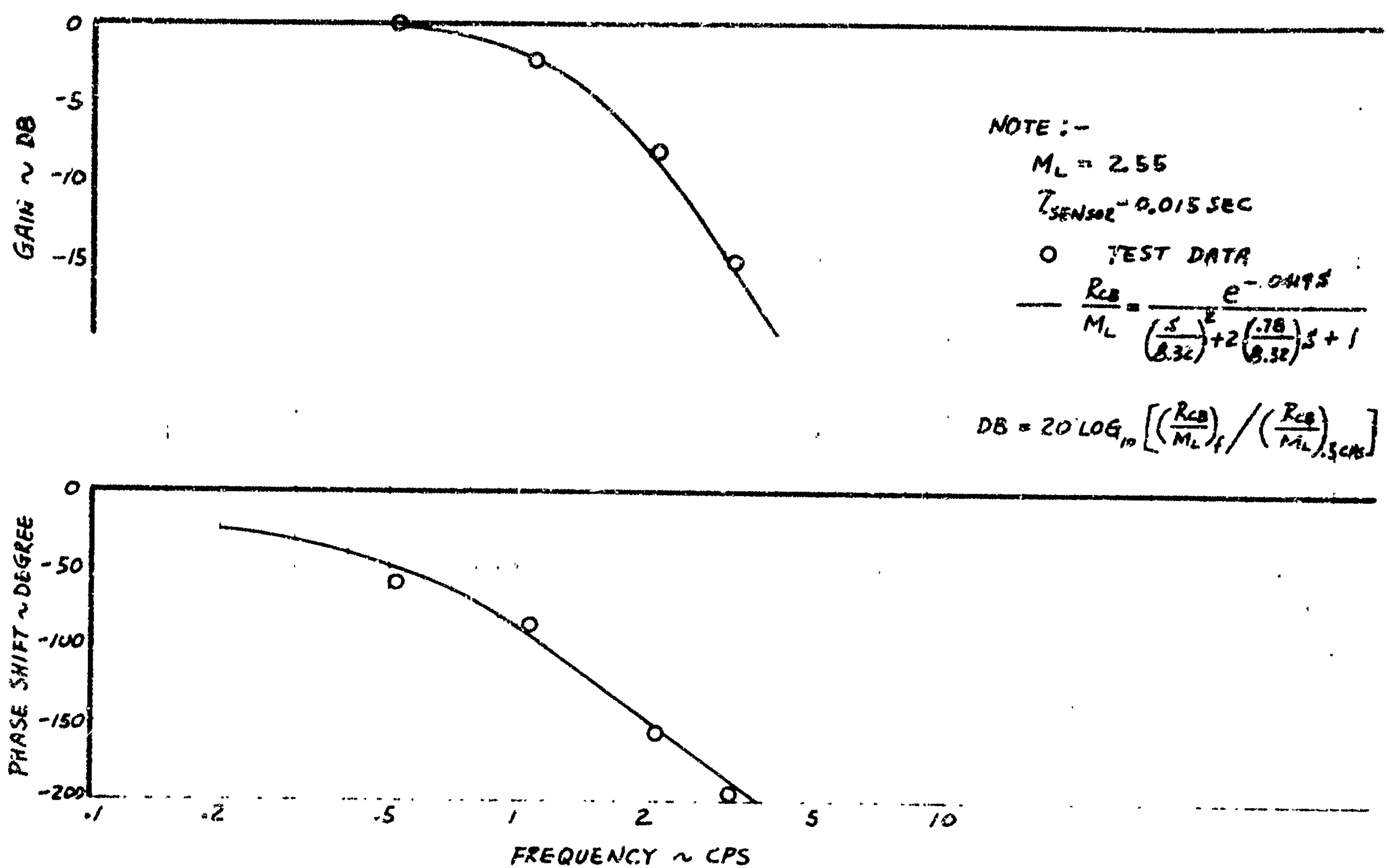


Figure 40. Centerbody Control Loop Response - Simulated Hydromechanical Sensor

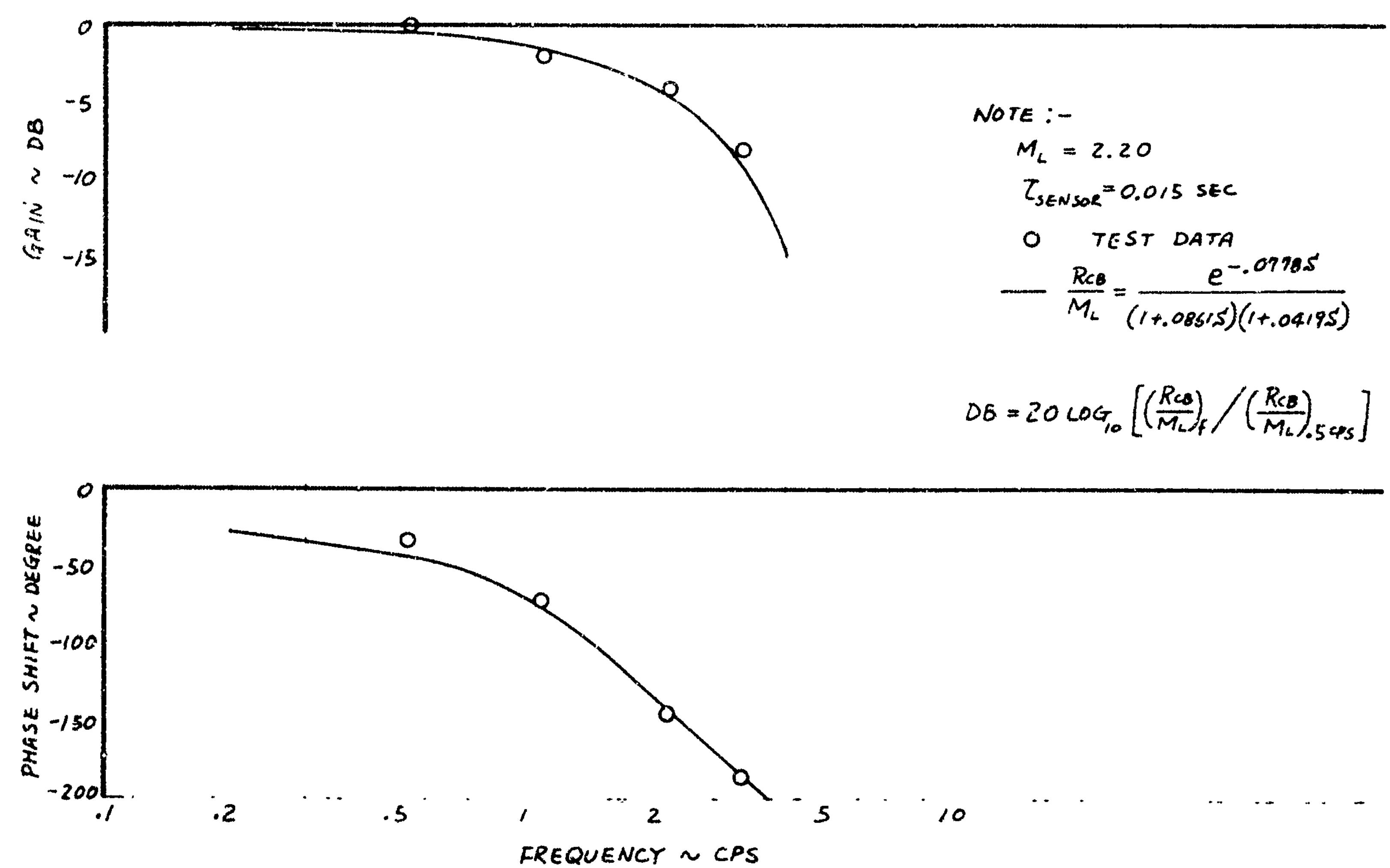


Figure 41. Centerbody Control Loop Response – Simulated Hydromechanical Sensor

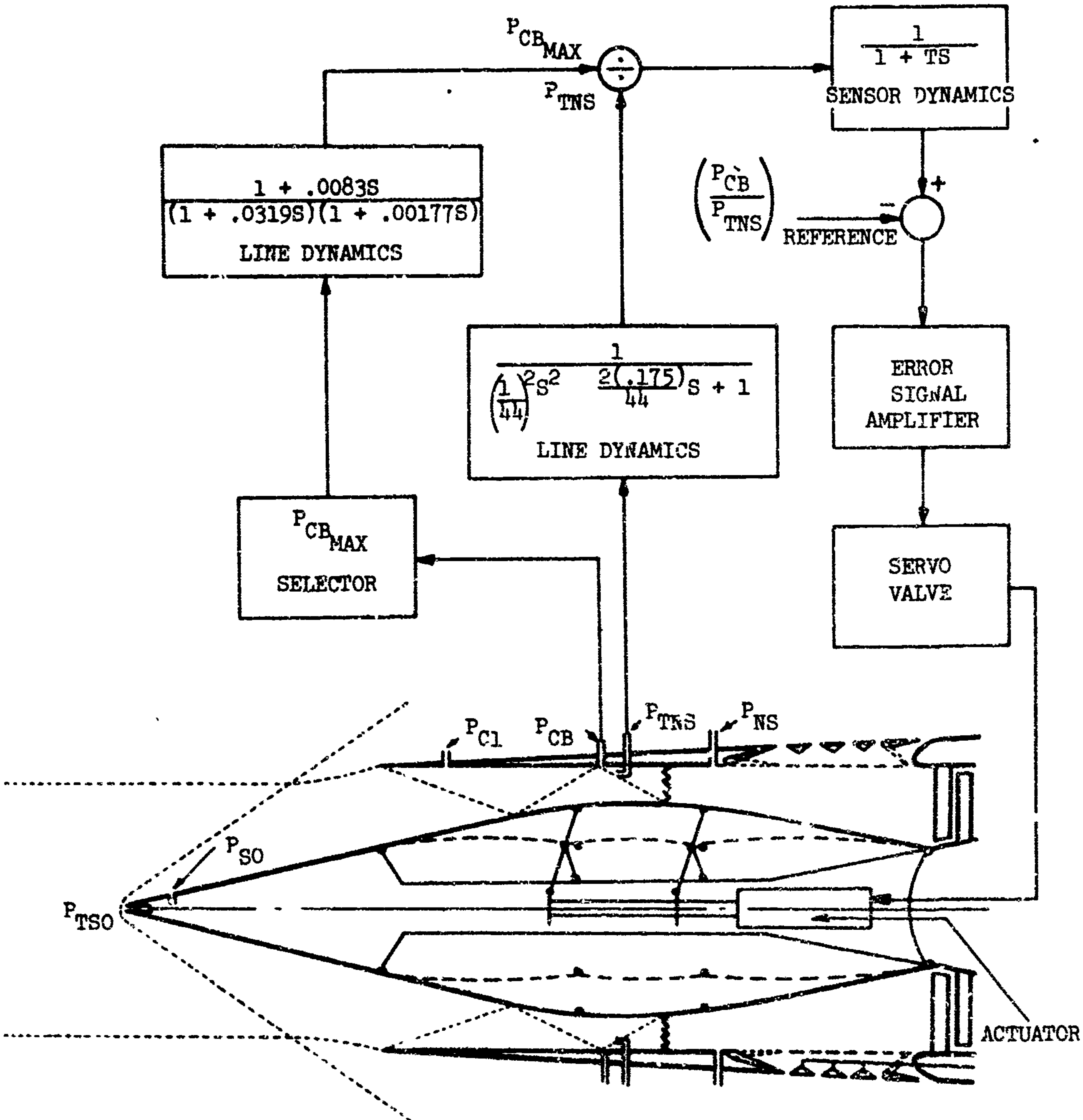


Figure 42. Inlet and Centerbody Control Loop

III. Description of Technical Progress (continued)

1303. Air Induction Control (continued)

(3) Coordination with Engine Manufacturers and Applied Theory Inc.
During the week of November 7, visits were made to P&WA of Florida; GE of Cincinnati, and Applied Theory Inc. of Los Angeles.

The purpose of the vists to the engine companies was to transmit information on the latest Boeing inlet mathematical model, to check out the operation of the inlet-engine mathematical model, and to discuss the future plans for inlet-engine compatibility studies.

The visit to Applied Theory was to explore the possibility of applying the AFTON Program developed by the company to the SST inlet dynamics problem. The AFTON Program is a digital program which solves unsteady fluid flow problems expressed in Navier-Stokes form. The program appeared to be an excellent tool for dynamic problems; however, more evaluation is necessary.

1305 Propulsion Installation

A proposal for a direct reading thrust indicating system was submitted to Boeing by AiResearch. Three separate coordination meetings between representatives of Boeing and AiResearch have taken place at Boeing during October and November.

Requirements for the Prototype Development Options for Phase III were established for the Propulsion system. Proposed differences include substitution of corrosion resistant steel for titanium and deletion of the auto throttle system as alternates for prototype development.

1306 Fuel System

(1) Thompson-Ramo-Woolridge Accessories Division has completed the developmental testing on the first test boost pump. Design changes to the impeller, reprime element, and motor cooling were made to meet specification requirements. These design changes were incorporated into the 3 qualification test pumps and the endurance test unit was started on October 24.

(2) Fuel cell testing is continuing at the two manufacturers as noted below:

A. Goodyear completed installation and checkout of equipment for automatic cycling at elevated temperatures to test 8 panels and 1 cube on May 20. On May 24 after 8 cycles leakage was detected, tear down revealed delamination of all test panels and the cube at the nylon fuel barrier. A backup cube was repaired and subjected to a bake-out procedure to remove any moisture from the nylon barrier. The cube was then installed in the test setup and cycled in

III Description of Technical Progress (continued)

1306 Fuel Systems (continued)

an attempt to find the cause for the failure. Progressive separation occurred in the bottom only without leakage for 276 cycles. During the next 12 cycles (on August 12) the temperature controller malfunctioned and the dry temperature reached 350-360°F. This charred and ruptured the cube in several places. Replacement cubes and panels have been fabricated and testing was resumed on November 18.

B. U. S. Rubber started testing of 4 panels and 1 cube on July 29. Leaks adjacent to the fittings were found in one panel and the cube. The cube leak was fixed with a standard repair. However, this cube was later damaged beyond repair in transit to the test facility. A replacement panel and cube was then put in work on September 22. Testing of the new cube was resumed on November 14. Testing is continuing satisfactorily on the 3 original panels which were placed in test on July 29.

1307 Exhaust/Reverser System

The pod location on the B-2707-100 airplane reduces the length of cut out required to expose the blow-in/thrust reverser doors above the stabilizer upper surface. The external boattail angle of the nozzle cowling is reduced by approximately 20 percent on the new pod configuration over the basic proposal pod configuration.

1308 Noise

The large scale jet noise suppression test program is proceeding at the recently activated Boardman, Oregon test facility using an afterburning J-75 turbojet. A photo of the test engine and acoustic field as viewed from the control room window, is shown in Fig. 43. A variety of configurations will be tested to investigate the effectiveness of ejector-mounted chutes and scoops, and afterburner primary nozzle shape. (See September 1966 Progress Report.) The test site is ideally suited to the acquisition of valid acoustic data and will be a great asset in the continuing program to evaluate various jet noise suppression concepts. The tests have begun and the data are currently being analyzed.

1309 Engine Coordination

(1) Pratt & Whitney Aircraft

A series of coordination meetings have been held with P&WA representatives to discuss installation requirements, mockup requirements, technical agreements, compressor, duct heater and nozzle design, inlet-engine compatibility, engine performance and growth, noise, reliability, and thrust measurement methods. Coordination meetings were held with P&WA on the following dates:

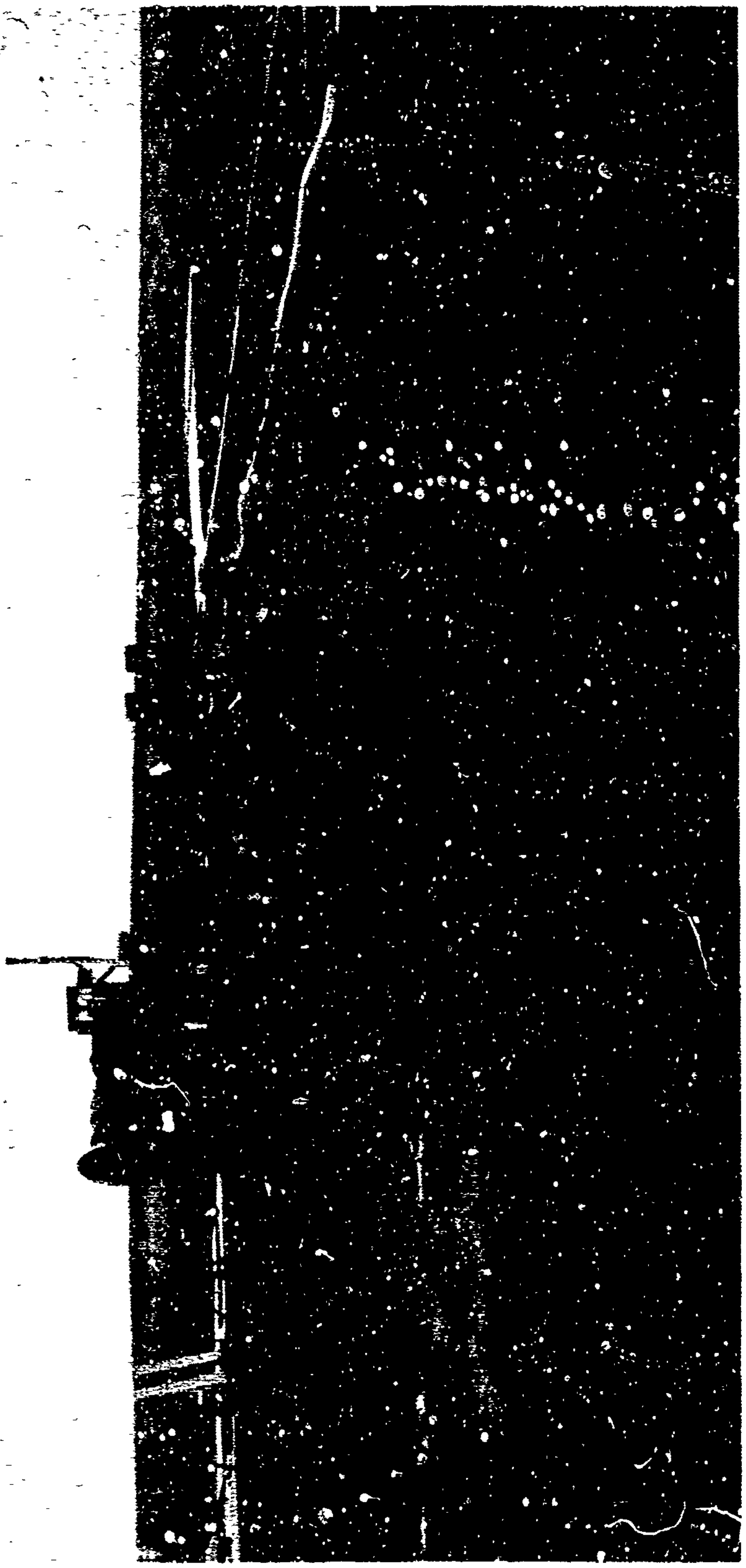


Figure 43. Test Engine and Acoustic Field

III Description of Technical Progress (continued)

1309 Engine Coordination (continued)

October 21	Airplane Growth Requirements (Seattle)
October 26	Duct Heater, Compressor, and Engine Control Design (Seattle)
November 1	Compressor Design Philosophy (East Hartford)
November 3, 4	Installation Requirements and Technical Agreement (West Palm Beach)
November 7, 8	Engine-Inlet Simulation (West Palm Beach)
November 8, 9	Airplane Mission Analysis (Seattle)
November 15	Thrust Measurement and Instrumentation (Seattle)
November 22	JTF17A-21B Development Status and Engine Scaling Information (Seattle)

Preliminary information on scaled JTF17A-21B cycle derivatives were presented by P&WA on November 22, 1966, to improve the engine-airplane matching characteristics. Performance and weight data were obtained from Pratt & Whitney for an 825 lb/sec engine with a bypass ratio of 1.1.

(2) General Electric Company

Coordination meetings were held with General Electric Company representatives to discuss installation requirements, noise, nozzle performance, afterburner development, compressor design philosophy, inlet-engine compatibility, engine controls and thrust measurement techniques. Coordination meetings were held with GE on the following dates:

November 1, 2	Installation Requirements, Controls, Nozzle Performance, Noise, Afterburner Development (Cincinnati)
November 3, 4	Compressor Design Philosophy (Cincinnati)
November 9	Engine-Inlet Simulation (Cincinnati)

14 PRODUCT SUPPORT

1400 Product Support – General

Coordination with the FAA and airlines was continued during this reporting period, with attendance at the FAA Maintenance Symposium in Washington, D.C., on November 2 - 4, and the ATA Engineering and Maintenance Conference in Los Angeles, California, on November 17 - 18.

1403 Training and Training Equipment

14030 TRAINING AND TRAINING EQUIPMENT - GENERAL

SST Training personnel attended a Boeing-sponsored conference on 747 training flight simulation during the week of October 24, 1966. Customer airlines in attendance were invited to make comments on a specification developed by Boeing for procurement of a 747 training flight simulator.

Presentations were made by six simulator manufacturers concerning their existing and near t[illegible] [illegible]abilities. A committee of Boeing and airline representation [illegible] to develop a common 747 simulator requirements specifica[illegible] [illegible]e manufacturers may use as a guide for future development [illegible]

1404 Ground Support Equipment

14041 SERVICE GROUND SUPPORT EQUIPMENT

Additional aft galley servicing conceptual studies were completed. A presentation on Galley Servicing Techniques and Concepts was made to the ATA Sub-committee for Food Service and Catering on SST and 747 type airplanes.

1405 Facilities

14051 AIRPORT COMPATIBILITY

Airport compatibility aspects of the B-2707 and 747 have been presented to domestic and international airlines, ATA Industries Facilities Group, airport operators, and airport planners during a series of conferences held in October and November.

The Boeing Supersonic Transport, "Ground Operations Planning Guide," D6A10308-1, has been completed and released to airlines, airport operators, and airport planning organizations. The guide provides airport requirements and ground operations planning data for the B-2707.

IV AIRLINE COORDINATION

A. Data for Airlines

Copies of seven 16mm sound and color movies on the Boeing SST program were mailed to the following U.S. and non-U.S. airlines to familiarize their personnel with the SST:

American Airlines	Alitalia Air Lines
Braniff International	BOAC
Continental Air Lines	Deutsche Lufthansa AG
Delta Airlines	El Al Israel Airlines
Eastern Air Lines	Irish International Airlines
National Airlines	Japan Air Lines
Northwest Airlines	KLM Royal Dutch Airlines
Pan American World Airways	Olympic Airways, S.A.
Trans World Airlines, Inc.	Pakistan International Airlines
United Air Lines	Qantas
Aeronaves de Mexico, S.A.	Sabena
Air Canada	Scandinavian Airlines System
Air France	South African Airways
Air India	SWISSAIR
Air New Zealand	Union de Transports Aeriens

Customer Engineering provided the airlines with additional technical data during the Boeing SST evaluation in response to their approximately fifty specific requests during October.

B. Visits of Airline Personnel

Personnel from the following airlines were given individual mockup tours and technical briefings:

Aerolineas Argentinas	Pan American Airways
Alitalia	Qantas Empire Airways
British Overseas Airways	Trans Caribbean Airways, Inc.
Japan Air Lines	Trans World Airlines
National Airlines	United Air Lines
Northwest Airlines	Western Airlines

Information obtained during these visits is summarized on the Airline Coordination Record forms that follow:

IV. Airline Coordination (continued)

C. Visits to Airlines

Engineering personnel visited the following airlines to familiarize their personnel with the refinements and improvements associated with the B-2707-100 airplane configuration:

- Air France
- Air India
- Alitalia
- American Airlines
- Braniff International
- British Overseas Airways
- Continental Air Lines
- Delta Airlines
- Eastern Air Lines
- El Al Israel Airlines
- Irish International Airlines
- Japan Air Lines
- KLM Royal Dutch Airlines
- Lufthansa German Airlines
- Northwest Airlines
- Pakistan International Airlines
- Pan American Airways
- Qantas Empire Airways
- Sabena Belgian World Airways
- Scandanavian Airlines Systems
- Swissair
- Trans World Airlines
- United Air Lines

D. Additional Briefings

Customer Engineering provided technical briefings and/or mockup tours for the following groups:

- Airline Pilots Association - SST Committee) Combined visit
- Allied Pilots Association - SST Committee)
- ATA Industries Facilities Group
- ATA Subcommittee on Passenger Service and Catering
- Electrical Wire and Connector Vendors
- Japanese Businessmen's Group
- SAE Intermountain Chapter

E. FAA/NASA Coordination

On October 28, Engineering personnel traveled to Washington, D.C. for a B-2707 design status review.

On November 7, the FAA Source Selection Council visited Boeing-Seattle for an SST briefing.

On November 14, Engineering personnel traveled to Washington, D.C. to present the B-2707-100 configuration.

On November 17-21, NASA/Langley personnel visited Boeing-Seattle for a B-2707-100 aerodynamics review.

On November 21, FAA regulatory personnel visited Boeing-Seattle to review the tentative FARs for SST operations.

IV. Airline Coordination (continued)

E. FAA/NASA Coordination (continued)

Approximately seventy transmittals of vendor progress reports, evaluation data, subsystem reliability analyses, and other engineering data were forwarded to the FAA/SST office and other government agency offices in response to Phase II-C detail work plan requirements, evaluation questions, and other requests.

BOEING SST

AIRLINE COORDINATION RECORD

cc: F.P.Blakeslee, R.Q.Wilson, N.D.Folling, W.T.Hamilton, L.T.Goodmanson, W.C.Becker, G.W.Taylor, H.J.Bostrom, S.N.Weiner, E.V.Mock

AIRLINE: Qantas Empire Airways DATE: 11-16-66

HELD AT: Sales Conference Room - Renton 3:30 p.m.

PARTICIPANTS:

Qantas		Boeing
R.C. Walker	Tech. Dev. Mgr.	W.T. Hamilton
T.M. Mansill	Resident Engr.	H.J. Bostrom
		W.C. Becker
		G. W. Taylor
		J.D. Anderson

GENERAL:

Walker and Mansill were briefed by Hamilton on the L/D and longitudinal control improvement program using the same data as presented to the FAA on Nov. 14th. Copies of documents V1-B2707-5 (B2707-100 description) and V1-2707-6 (Nov. 14 oral) were left with them following the discussions - a brief discussion on engine inlet flow distortion and high speed directional stability was also held.

SPECIFIC COMMENTS BY AIRLINE:

BOEING POSITION ON AIRLINE COMMENTS:

cc: S.N.Weiner
H.J.Bostrom
W.C.Becker
L.T.Goodmanson
JAL File

BOEING SST

AIRLINE COORDINATION RECORD

AIRLINE: Japan Air Lines DATE: 10-29-66

HELD AT: Developmental Center

PARTICIPANTS:

JAL		Boeing
C. Noda	Engineering Manager	L. T. Goodmanson
K. Furukawa	Res. Representative(Renton)	J.M.Swihart
M. Kitamoto	Eng. Representative(Renton)	W.C.Becker
		B.H.Miller
		H.J.Bostrom

GENERAL:

1) Mockup Tour and Discussion on L/D and Longitudinal Control improvement programs.
2) General discussion on 633 PPS GE engine performance on 675,000, 750,000 and 825,000 lb airplanes.
3) Clarification of subsonic stability characteristics as discussed in proposal documentation.

SPECIFIC COMMENTS BY AIRLINE:

1) Question from Tani (Tokyo) regarding cross-coupling of controls was not adequately defined to resolve. Kitamoto to obtain further clarification of question.
2) Questions on 750,000 lb airplane route analysis referred to Hank Montgomery to resolve. (10-31-66 by HJB)

BOEING POSITION ON AIRLINE COMMENTS:

Mr. Noda given selected data from October 28 FAA briefing on L/D, longitudinal control and 633 PPS GE engine performance.

S. N. Weiner
F. P. Blakeslee
W. R. Horner
F. H. Brown
C. Hrott

J. R. Gannett

BOEING SST

AIRLINE COORDINATION RECORD

AIRLINE: United Air Lines DATE: Oct. 28, 1966

HELD AT: SST Mockup

PARTICIPANTS: W. R. Horner CE | Mr. R Froom
Capt. McFadden
Capt. Renn
Capt. Weisner

GENERAL: The above four United personnel are flight managers stationed at Sea Tac. They were given a general tour of the SST Mockup.

SPECIFIC COMMENTS BY AIRLINE:

Capt. McFadden and Capt. Renn were particularly concerned about the Capt. and first officer being able to quickly evacuate in the event of an emergency They felt that if electrical power failed during an emergency that it would be difficult for them to get out of their seats and egress out the escape hatches in a reasonable amount of time.

BOEING POSITION ON AIRLINE COMMENTS:

This comment tc be considered during future design efforts.

BOEING SST

cc: W.C.Becker
H.L.Adams
S.N.Weiner
A.T.Burdo
H.A.Lacey

AIRLINE COORDINATION RECORD

AIRLINE: Pan American World Airways DATE: 10-25-66

HELD AT: Boeing SST Developmental Center

PARTICIPANTS:

Harold Graham	V.P. Cargo Sales	Boeing
H. F. Milley	V.P. Traffic & Sales	R. Q. Wilson
~~C. "Chile" Vaughn~~	~~V.P. Operations~~	
Glen Caldwell	Superintendent Acft. Eng.	A. T. Burdo
Lloyd Wilson	Mgr. Flight Services	H. A. Lacey
~~E. Poo~~	~~Flight Services~~	
Chas. Forbert	Interior Consultant	J. Sterling
T. S. Cronier	Resident Staff Engr.	

GENERAL:

An after hours SST Mockup tour and briefing was given to the above PAA people. Particular emphasis was given to the Interior, Flight Deck and Major Systems.

SPECIFIC COMMENTS BY AIRLINE:

1. Considerable interest was expressed in some of the interior items, e.g. seat concept, video phone, lighting, and unitized galley units.

2. PAA was glad to hear the SST was receiving much thought or egress and advance thinking such as the "Braille" system for dark or smoke filled cabins.

3. The complete interior was favorably received.

BOEING POSITION ON AIRLINE COMMENTS:

cc: S.N.Weiner
A.T.Burdo
H.L.Adams
W.C.Becker

BOEING SST

AIRLINE COORDINATION RECORD

AIRLINE: Trans World Airline DATE: 10-18-66

HELD AT: Boeing SST Developmental Center

PARTICIPANTS: TWA Personnel: Boeing Personnel:

See attachment R. Q. Wilson

A. T. Burdo

GENERAL:

This TWA group was primarily interested in facilities required for future airplanes, i.e. 747 and SST type. The mockup tour covered the general qualities of the SST and more detailed inspection of cargo and baggage handling facilities that may be required.

SPECIFIC COMMENTS BY AIRLINE:

1. The T.V. camera location as shown on the mockup would be subject to dammage. It was estimated that dammage would occur to the ventral at least once a month.

2. Passenger loading equipment for 747 type aircraft appear to be adaptable to our SST.

Most TWA personnel were very much impressed with the overall mockup.

BOEING POSITION ON AIRLINE COMMENTS:

1. The optimum position for T.V. will have to be determined considering all factors including rain, slush, over rotation, and ground handling equipment.

2. It is our intent to make the Boeing SST compatible with passenger and ground handling equipment with a minimum of special "SST" type equipment.

TWA Personnel:

G. W. McKenzie
Manager - Airframe Development
E. R. Gilbert
Supervisor - Aircraft Structures Development
R. L. Ewing
K. E. Bostwick
Manager - Cargo Systems Development
A. N. Knudsen
Director - Customer Service Equipment and Facilities Planning
R. L. Citarell
Master Engineer
G. Moen
Director of Profit Analysis
R. C. Santy
Economist - Economy Planning
Ken Bauman
Aircraft Structure Modification Eng.
F. B. Carter
Dortech Representative
Mort Breier
Dortech Representative
Hans Marx
Dortech Representative
W. E. Rankin
J. S. Nelson
J. A. Heard
Mr. GorGeske

cc: S.N.Weiner, R.Q.Wilson, L.T.Goodmanson, J.R.Gannett, W.C.Becker, H.J.Bostrom, NWA file

BOEING SST

AIRLINE COORDINATION RECORD

AIRLINE: NORTHWEST AIRLINES, INC. **DATE:** 10-8-66

HELD AT: Developmental Center

PARTICIPANTS:

Northwest Airlines, Inc.	Boeing
D.W. Nyrop - President	M.L. Pennell
C.L. Stewart - Vice Pres.-Economic Planning	T.A. Wilson
B.G. Griggs - Vice Pres.-Flight Operations	L.T. Goodmanson
Frank Judd - Vice Pres. - Maintenance&Engineering	W.C.Becker
Paul Soderlind - Chief Eng. Pilot	J.R. Gannett
C.A. Eklund - Chief Pilot - Eastern Division	H.J. Bostrom
Jim Robinson - Director In-Flight Services	D. Bales

GENERAL:

General presentation on proposal configuration, advantages of variable sweep, program status, maintenance cost aspects and tour of Mockup.

SPECIFIC COMMENTS BY AIRLINE:

Frank Judd was further interested in maintanance costs and was given an economic document on these cost factors. He intends to return in the near future with some of his key people for a more inclusive briefing and to see the Technical Briefing Area for which there was not enough time.

Paul Soderlind and Chet Eklund were shown Mockup Cockpit and Simulator by Jim Gannett. They will plan to return to fly Simulator and see Kent Vision Simulator at some future date.

~~**BOEING POSITION ON AIRLINE COMMENTS:**~~

cc: S. N. Weiner
F. A. Maxam
H. W. Withington
H. A. Lacey
F. P. Blakeslee

BOEING SST

AIRLINE COORDINATION RECORD

AIRLINE: UNITED AIR LINES — DATE: October 3, 1966

HELD AT: DEVELOPMENTAL CENTER

PARTICIPANTS:

UAL		BOEING
Homer Merchant	V/P Sales	M. L. Pennell
R. E. Johnson	V/P Marketing	C. Jackson
		H. Thorson
		F. Blakeslee

GENERAL:

They were given a one hour tour of the mockup.

SPECIFIC COMMENTS BY AIRLINE:

1. They were quite interested in the possibility of sonic boom restrictions.
2. They pointed out that in the area of meal service considerable work is still to be done.
3. The wide body with double aisle attracted favorable comment due to its flexibility.
4. The SST concept seat may have some merit provided its development is continued.

BOEING POSITION ON AIRLINE COMMENTS:

1. The advantages of variable sweep in the case of boom restrictions was pointed out. The sonic boom unknowns were reviewed.
2. We are working the meal service problem.
3. We are prepared to build the wide body.
4. We plan to continue development of SST concept seat.

B. MANUFACTURING DEVELOPMENT

1. Manufacturing Process Development and Refinement

(a) Riveting

A new concept in riveting has been developed. Two opposing dies are simultaneously driven by spiral wound pancake-shaped magnetic coils energized by the discharge of a high-energy capacitor bank. This generates equal and opposite forging forces on the rivet. By utilizing mass inertia reaction force damping a lightweight framework to provide rivet head alignment can be used instead of the massive C frames typical of present riveting equipment. Forging forces are controlled by adjusting the voltage applied to the capacitor bank. Fatigue life tests of rivets installed by this method produce values at least equal to results obtained by present conventional squeeze methods.

(b) Welding

Significant advancements were made in the welding of sine wave structure. Simplified tooling in the form of two parallel bars to retain the web laterally showed promise in replacing the complex, costly "hard" tooling originally used. Development of a single-pass weld using CP filler wire having sufficient top bead reinforcement showed promise in eliminating the more costly and time-consuming two-pass weld using no filler wire in the first and a cover pass with filler wire in the second pass.

(c) Chemical Milling

A mechanical fully controllable technique for taper chemical milling titanium sheets has been established. The process controls the stripping of the maskant from the metal while it is submerged in the chemical milling solution. Appropriate linkage powered by a variable speed electric motor programs the maskant removal. Control of maskant removal rate and the etch rate of the solution produces configurations having long continuous tapers, steps; or combinations of steps and tapers.